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Example 2.2  Using SQL to read table data into a C struct . . . . . . . . . . . . . . . . . . 25
The InterBase Embedded SQL Guide is a task-oriented explanation of how to write, preprocess, compile, and link embedded SQL and DSQL database applications using InterBase and a *host programming language*, either C or C++. This chapter describes who should read this book, and provides a brief overview of its chapters.

**Who should use this guide**

The InterBase Embedded SQL Guide is intended for database applications programmers. It assumes a general knowledge of:

- SQL
- Relational database programming
- C programming

The Embedded SQL Guide assumes little or no previous experience with InterBase. See the Operations Guide for an introduction to InterBase and the Language Reference for an introduction to SQL.
Note  The *Embedded SQL Guide* focuses on embedded SQL and DSQL programming in C or C++. It does not address Delphi-specific topics.

### Topics covered in this guide

The following table provides a brief description of each chapter in this *Embedded SQL Guide*:

<table>
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<td>Chapter 1, “Using the Embedded SQL Guide”</td>
<td>Introduces the structure of the book and describes its intended audience.</td>
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<td>Chapter 2, “Application Requirements”</td>
<td>Describes elements common to programming all SQL and DSQL applications.</td>
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<tr>
<td>Chapter 3, “Working with Databases”</td>
<td>Describes using SQL statements that deal with databases.</td>
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<td>Chapter 4, “Working with Transactions”</td>
<td>Explains how to use and control transactions with SQL statements.</td>
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<td>Chapter 5, “Working with Data Definition Statements”</td>
<td>Describes how to embed SQL data definition statements in applications.</td>
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<td>Chapter 6, “Working with Data”</td>
<td>Explains how to select, insert, update, and delete standard SQL data in applications.</td>
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<td>Chapter 7, “Working with Dates”</td>
<td>Describes how to select, insert, update, and delete DATE, TIME, and TIMESTAMP data in applications.</td>
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<td>Chapter 8, “Working with Blob Data”</td>
<td>Describes how to select, insert, update, and delete Blob data in applications.</td>
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<tr>
<td>Chapter 9, “Using Arrays”</td>
<td>Describes how to select, insert, update, and delete array data in applications.</td>
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<tr>
<td>Chapter 10, “Working with Stored Procedures”</td>
<td>Explains how to call stored procedures in applications.</td>
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<td>Chapter 11, “Working with Events”</td>
<td>Explains how triggers interact with applications. Describes how to register interest in events, wait on them, and respond to them in applications.</td>
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<td>Chapter 12, “Error Handling and Recovery”</td>
<td>Describes how to trap and handle SQL statement errors in applications.</td>
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**TABLE 1.1** Chapters in the InterBase 6 *Embedded SQL Guide*
Sample database and applications

@The InterBase examples subdirectory contains several subdirectories containing useful items worth noting, including:

- **UDF subdirectory** The ib_udf.sql file, which declares the UDFs in the library provided by InterBase; the library of UDFs is in the InterBase lib subdirectory and is named ib_udf.dll on Wintel platforms and ib_udf on UNIX platforms

- **Database subdirectory** A sample database, employee.gdb

- **API subdirectory** Sample application source code, which produces several sample applications when compiled; see the makefile and the readme in the examples directory for more information about the sample applications and how to compile them

The Embedded SQL Guide makes use of the sample database and source code for its examples wherever possible.
CHAPTER 2

Application Requirements

This chapter describes programming requirements for InterBase SQL and dynamic SQL (DSQL) applications. Many of these requirements may also affect developers moving existing applications to InterBase.

Requirements for all applications

All embedded applications must include certain declarations and statements to ensure proper handling by the InterBase preprocessor, gpre, and to enable communication between SQL and the host language in which the application is written. Every application must:

- Declare host variables to use for data transfer between SQL and the application.
- Declare and set the databases accessed by the program.
- Create transaction handles for each non-default transaction used in the program.
- Include SQL (and, optionally, DSQL) statements.
- Provide error handling and recovery.
- Close all transactions and databases before ending the program.
Dynamic SQL applications, those applications that build SQL statements at run time, or enable users to build them, have additional requirements. For more information about DSQL requirements, see “DSQL requirements” on page 30.

For more information about using gpre, see Chapter 14, “Preprocessing, Compiling, and Linking.”

Porting considerations for SQL

When porting existing SQL applications to InterBase, other considerations may be necessary. For example, many SQL variants require that host variables be declared between BEGIN DECLARE SECTION and END DECLARE SECTION statements; InterBase has no such requirements, but gpre can correctly handle section declarations from ported applications. For additional portability, declare all host-language variables within sections.

Porting considerations for DSQL

When porting existing DSQL applications to InterBase, statements that use another vendor’s SQL descriptor area (SQLDA) must be modified to accommodate the extended SQLDA (XSQLDA) used by InterBase.

Declaring host variables

A host variable is a standard host-language variable used to hold values read from a database, to assemble values to write to a database, or to store values describing database search conditions. SQL uses host variables in the following situations:

- During data retrieval, SQL moves the values in database fields into host variables where they can be viewed and manipulated.
- When a user is prompted for information, host variables are used to hold the data until it can be passed to InterBase in an SQL INSERT or UPDATE statement.
- When specifying search conditions in a SELECT statement, conditions can be entered directly, or in a host variable. For example, both of the following SQL statement fragments are valid WHERE clauses. The second uses a host-language variable, country, for comparison with a column, COUNTRY:

  ... WHERE COUNTRY = 'Mexico';
  ... WHERE COUNTRY = :country;
One host variable must be declared for every column of data accessed in a database. Host variables may either be declared globally like any other standard host-language variable, or may appear within an SQL section declaration with other global declarations. For more information about reading from and writing to host variables in SQL programs, see Chapter 6, “Working with Data.”

Host variables used in SQL programs are declared just like standard language variables. They follow all standard host-language rules for declaration, initialization, and manipulation. For example, in C, variables must be declared before they can be used as host variables in SQL statements:

```
int empno; char fname[26], lname[26];
```

For compatibility with other SQL variants, host variables can also be declared between BEGIN DECLARE SECTION and END DECLARE SECTION statements.

### Section declarations

Many SQL implementations expect host variables to be declared between BEGIN DECLARE SECTION and END DECLARE SECTION statements. For portability and compatibility, InterBase supports section declarations using the following syntax:

```
EXEC SQL
   BEGIN DECLARE SECTION;
       <hostvar>;
   . . .
EXEC SQL
   END DECLARE SECTION;
```

For example, the following C code fragment declares three host variables, `empno`, `fname`, and `lname`, within a section declaration:

```
EXEC SQL
   BEGIN DECLARE SECTION;
       int empno;
       char fname[26];
       char lname[26];
EXEC SQL
   END DECLARE SECTION;
```

Additional host-language variables not used in SQL statements can be declared outside DECLARE SECTION statements.
**Using BASED ON to declare variables**

InterBase supports a declarative clause, BASED ON, for creating C language character variables based on column definitions in a database. Using BASED ON ensures that the resulting host-language variable is large enough to hold the maximum number of characters in a CHAR or VARCHAR database column, plus an extra byte for the null-terminating character expected by most C string functions.

BASED ON uses the following syntax:

```
BASED ON <dbcolumn> hostvar;
```

For example, the following statements declare two host variables, `fname` and `lname`, based on two column definitions, `FIRSTNAME` and `LASTNAME`, in an employee database:

```
BASED ON EMP.FIRSTNAME fname;
BASED ON EMP.LASTNAME lname;
```

Embedded in a C or C++ program, these statements generate the following host-variable declarations during preprocessing:

```
char fname[26];
char lname[26];
```

To use BASED ON, follow these steps:

1. Use `SET DATABASE` to specify the database from which column definitions are to be drawn.
2. Use `CONNECT` to attach to the database.
3. Declare a section with `BEGIN DECLARE SECTION`.
4. Use the BASED ON statement to declare a string variable of the appropriate type.

The following statements show the previous BASED ON declarations in context:

```
EXEC SQL
    SET DATABASE EMP = 'employee.gdb';
EXEC SQL
    CONNECT EMP;
EXEC SQL
    BEGIN DECLARE SECTION;
        int empno;
        BASED ON EMP.FIRSTNAME fname;
        BASED ON EMP.LASTNAME lname;
EXEC SQL
    END DECLARE SECTION;
```
**Host-language data structures**

If a host language supports data structures, data fields within a structure can correspond to a collection of database columns. For example, the following C declaration creates a structure, `BILLING_ADDRESS`, that contains six variables, or *data members*, each of which corresponds to a similarly named column in a table:

```c
struct {
    char fname[25];
    char lname[25];
    char street[30];
    char city[20];
    char state[3];
    char zip[11];
} billing_address;
```

SQL recognizes data members in structures, but information read from or written to a structure must be read from or written to individual data members in SQL statements. For example, the following SQL statement reads data from a table into variables in the C structure, `BILLING_ADDRESS`:

```sql
EXEC SQL
SELECT FNAME, LNAME, STREET, CITY, STATE, ZIP
    INTO :billing_address.fname, :billing_address.lname,
       :billing_address.street, :billing_address.city,
       :billing_address.state, :billing_address.zip
FROM ADDRESSES WHERE CITY = 'Brighton';
```

**Declaring and initializing databases**

An SQL program can access multiple InterBase databases at the same time. Each database used in a multiple-database program must be declared and initialized before it can be accessed in SQL transactions. Programs that access only a single database need not declare the database or assign a database handle if, instead, they specify a database on the `gpre` command line.

**IMPORTANT** DSQI programs cannot connect to multiple databases.
InterBase supports the following SQL statements for handling databases:

- **SET DATABASE** declares the name of a database to access, and assigns it to a database handle.
- **CONNECT** opens a database specified by a handle, and allocates it system resources. Database handles replace database names in CONNECT statements. They can also be used to qualify table names within transactions. For a complete discussion of database handling in SQL programs, see Chapter 3, “Working with Databases.”

**Using SET DATABASE**

The SET DATABASE statement is used to:

- Declare a database handle for each database used in an SQL program.
- Associate a database handle with an actual database name. Typically, a database handle is a mnemonic abbreviation of the actual database name.

SET DATABASE instantiates a host variable for the database handle without requiring an explicit host variable declaration. The database handle contains a pointer used to reference the database in subsequent SQL statements. To include a SET DATABASE statement in a program, use the following syntax:

```sql
EXEC SQL
    SET DATABASE handle = 'dbname';
```

A separate statement should be used for each database. For example, the following statements declare a handle, DB1, for the `employee.gdb` database, and another handle, DB2, for `employee2.gdb`:

```sql
EXEC SQL
    SET DATABASE DB1 = 'employee.gdb';
EXEC SQL
    SET DATABASE DB2 = 'employee2.gdb';
```

Once a database handle is created and associated with a database, the handle can be used in subsequent SQL database and transaction statements that require it, such as CONNECT.

**Note** SET DATABASE also supports user name and password options. For a complete discussion of SET DATABASE options, see Chapter 3, “Working with Databases.”
Using CONNECT

The CONNECT statement attaches to a database, opens the database, and allocates system resources for it. A database must be opened before its tables can be used. To include CONNECT in a program, use the following syntax:

```sql
EXEC SQL
    CONNECT handle;
```

A separate statement can be used for each database, or a single statement can connect to multiple databases. For example, the following statements connect to two databases:

```sql
EXEC SQL
    CONNECT DB1;
EXEC SQL
    CONNECT DB2;
```

The next example uses a single CONNECT to establish both connections:

```sql
EXEC SQL
    CONNECT DB1, DB2;
```

Once a database is connected, its tables can be accessed in subsequent transactions. Its handle can qualify table names in SQL applications, but not in DSQL applications. For a complete discussion of CONNECT options and using database handles, see Chapter 3, “Working with Databases.”

Working with a single database

In single-database programs preprocessed without the `gpre -m` switch, SET DATABASE and CONNECT are optional. The `-m` switch suppresses automatic generation of transactions. Using SET DATABASE and CONNECT is strongly recommended, however, especially as a way to make program code as self-documenting as possible. If you omit these statements, take the following steps:

1. Insert a section declaration in the program code where global variables are defined. Use an empty section declaration if no host-language variables are used in the program. For example, the following declaration illustrates an empty section declaration:

   ```sql
   EXEC SQL
   BEGIN DECLARE SECTION;
   EXEC SQL
   END DECLARE SECTION;
   ```
2. Specify a database name on the gpre command line at precompile time. A database need not be specified if a program contains a CREATE DATABASE statement.

For more information about working with a single database in an SQL program, see Chapter 3, “Working with Databases.”

**SQL statements**

An SQL application consists of a program written in a host language, like C or C++, into which SQL and dynamic SQL (DSQL) statements are embedded. Any SQL or DSQL statement supported by InterBase can be embedded in a host language. Each SQL or DSQL statement must be:

- Preceded by the keywords EXEC SQL.
- Ended with the statement terminator expected by the host language. For example, in C and C++, the host terminator is the semicolon (;).

For a complete list of SQL and DSQL statements supported by InterBase, see the Language Reference.

**Error handling and recovery**

Every time an SQL statement is executed, it returns an error code in the SQLCODE variable. SQLCODE is declared automatically for SQL programs during preprocessing with gpre. To catch run-time errors and recover from them when possible, SQLCODE should be examined after each SQL operation.

SQL provides the WHENEVER statement to monitor SQLCODE and direct program flow to recovery procedures. Alternatively, SQLCODE can be tested directly after each SQL statement executes. For a complete discussion of SQL error handling and recovery, see Chapter 12, “Error Handling and Recovery.”

**Closing transactions**

Every transaction should be closed when it completes its tasks, or when an error occurs that prevents it from completing its tasks. Failure to close a transaction before a program ends can cause limbo transactions, where records are entered into the database, but are neither committed or rolled back. Limbo transactions can be cleaned up using the database administration tools provided with InterBase.
Accepting changes

The COMMIT statement ends a transaction, makes the transaction's changes available to other users, and closes cursors. A COMMIT is used to preserve changes when all of a transaction's operations are successful. To end a transaction with COMMIT, use the following syntax:

EXEC SQL
  COMMIT TRANSACTION name;

For example, the following statement commits a transaction named MYTRANS:

EXEC SQL
  COMMIT TRANSACTION MYTRANS;

For a complete discussion of SQL transaction control, see Chapter 4, “Working with Transactions.”

Undoing changes

The ROLLBACK statement undoes a transaction's changes, ends the current transaction, and closes open cursors. Use ROLLBACK when an error occurs that prevents all of a transaction's operations from being successful. To end a transaction with ROLLBACK, use the following syntax:

EXEC SQL
  ROLLBACK TRANSACTION name;

For example, the following statement rolls back a transaction named MYTRANS:

EXEC SQL
  ROLLBACK TRANSACTION MYTRANS;

To roll back an unnamed transaction (i.e., the default transaction), use the following statement:

EXEC SQL
  ROLLBACK;

For a complete discussion of SQL transaction control, see Chapter 4, “Working with Transactions.”
Closing databases

Once a database is no longer needed, close it before the program ends, or subsequent attempts to use the database may fail or result in database corruption. There are two ways to close a database:

- Use the DISCONNECT statement to detach a database and close files.
- Use the RELEASE option with COMMIT or ROLLBACK in a program.

DISCONNECT, COMMIT RELEASE, and ROLLBACK RELEASE perform the following tasks:

- Close open database files.
- Close remote database connections.
- Release the memory that holds database descriptions and InterBase engine-compiled requests.

**Note** Closing databases with DISCONNECT is preferred for compatibility with the SQL-92 standard.

For a complete discussion of closing databases, see Chapter 3, “Working with Databases.”

DSQL requirements

DSQL applications must adhere to all the requirements for all SQL applications and meet additional requirements as well. DSQL applications enable users to enter ad hoc SQL statements for processing at run time. To handle the wide variety of statements a user might enter, DSQL applications require the following additional programming steps:

- Declare as many extended SQL descriptor areas (XSQLDAs) as are needed in the application; typically a program must use one or two of these structures. Complex applications may require more.
- Declare all transaction names and database handles used in the program at compile time; names and handles are not dynamic, so enough must be declared to accommodate the anticipated needs of users at run time.
- Provide a mechanism to get SQL statements from a user.
- Prepare each SQL statement received from a user for processing.
  PREPARE loads statement information into the XSQLDA.
- EXECUTE each prepared statement.
EXECUTE IMMEDIATE combines PREPARE and EXECUTE in a single statement. For more information, see the Language Reference.

In addition, the syntax for cursors involving Blob data differs from that of cursors for other datatypes. For more information about Blob cursor statements, see the Language Reference.

---

**Declaring an XSQLDA**

The extended SQL descriptor area (XSQLDA) is used as an intermediate staging area for information passed between an application and the InterBase engine. The XSQLDA is used for either of the following tasks:

- Pass input parameters from a host-language program to SQL.
- Pass output, from a SELECT statement or stored procedure, from SQL to the host-language program.

A single XSQLDA can be used for only one of these tasks at a time. Many applications declare two XSQLDAs, one for input, and another for output.

The XSQLDA structure is defined in the InterBase header file, `ibase.h`, that is automatically included in programs when they are preprocessed with `gpre`.

**IMPORTANT** DSQL applications written using versions of InterBase prior to 3.3 use an older SQL descriptor area, the SQLDA. The SQLDA and the `gpre-sqlda` switch are no longer supported. Older applications should be modified to use the XSQLDA.

To create an XSQLDA for a program, a host-language datatype of the appropriate type must be set up in a section declaration. For example, the following statement creates two XSQLDA structures, `inxsqlda`, and `outxsqlda`:

```sql
  . . .
  EXEC SQL
    BEGIN DECLARE SECTION;
      XSQLDA inxsqlda;
      XSQLDA outxsqlda;
    . . .
  EXEC SQL
    END DECLARE SECTION;
  . . .
```
When an application containing XSQLDA declarations is preprocessed, \texttt{gpre} automatically includes the header file, \texttt{ibase.h}, which defines the XSQLDA as a host-language datatype. For a complete discussion of the structure of the XSQLDA, see Chapter 13, “Using Dynamic SQL.”

**DSQL limitations**

DSQL enables programmers to create flexible applications that are capable of handling a wide variety of user requests. Even so, not every SQL statement can be handled in a completely dynamic fashion. For example, database handles and transaction names must be specified when an application is written, and cannot be changed or specified by users at run time. Similarly, while InterBase supports multiple databases and multiple simultaneous transactions in an application, the following limitations apply:

- Only a single database can be accessed at a time.
- Transactions can only operate on the currently active database.
- Users cannot specify transaction names in DSQL statements; instead, transaction names must be supplied and manipulated when an application is coded.

**Using database handles**

Database handles are always static, and can only be declared when an application is coded. Enough handles must be declared to satisfy the expected needs of users. Once a handle is declared, it can be assigned to a user-specified database at run time with \texttt{SET DATABASE}, as in the following C code fragment:

```c
... 
EXEC SQL
  SET DATABASE DB1 = 'dummydb.gdb';
EXEC SQL
  SET DATABASE DB2 = 'dummydb.gdb';
...
printf("Specify first database to open: ");
gets(fname1); 
printf("\nSpecify second database to open: ");
gets(fname2);
EXEC SQL
  SET DATABASE DB1 = :fname1;
EXEC SQL
```
SET DATABASE DB2 = :fname2;

For a complete discussion of SET DATABASE, see Chapter 3, “Working with Databases.”

Using the active database

A DSQL application can only work with one database at a time, even if the application attaches to multiple databases. All DSQL statements operate only on the currently active database, the last database associated with a handle in a SET DATABASE statement.

Embedded SQL statements within a DSQL application can operate on any open database. For example, all DSQL statements entered by a user at run time might operate against a single database specified by the user, but the application might also contain non-DSQL statements that record user entries in a log database.

For a complete discussion of SET DATABASE, see Chapter 3, “Working with Databases.”

Using transaction names

Many SQL statements support an optional transaction name parameter, used to specify the controlling transaction for a specific statement. Transaction names can be used in DSQL applications, too, but must be set up when an application is compiled. Once a name is declared, it can be directly inserted into a user statement only by the application itself.

After declaration, use a transaction name in an EXECUTE or EXECUTE IMMEDIATE statement to specify the controlling transaction, as in the following C code fragment:

```c
EXEC SQL
    BEGIN DECLARE SECTION:
        long first, second; /* declare transaction names */
    EXEC SQL
    END DECLARE SECTION;

first = second = 0L; /* initialize names to zero */

EXEC SQL
    SET TRANSACTION first; /* start transaction 1 */
EXEC SQL
    SET TRANSACTION second; /* start transaction 2 */
```
printf("\nSQL> ");
gets(userstatement);
EXEC SQL
   EXECUTE IMMEDIATE TRANSACTION first userstatement;
...
For complete information about named transactions, see Chapter 4, “Working with Transactions.”

Preprocessing programs

After an SQL or DSQL program is written, and before it is compiled and linked, it must be preprocessed with gpre, the InterBase preprocessor. gpre translates SQL statements and variables into statements and variables that the host-language compiler accepts. For complete information about preprocessing with gpre, see Chapter 14, “Preprocessing, Compiling, and Linking.”
This chapter describes how to use SQL statements in embedded applications to control databases. There are three database statements that set up and open databases for access:

- **SET DATABASE** declares a database handle, associates the handle with an actual database file, and optionally assigns operational parameters for the database.

- **SET NAMES** optionally specifies the character set a client application uses for CHAR, VARCHAR, and text Blob data. The server uses this information to transliterate from a database’s default character set to the client’s character set on SELECT operations, and to transliterate from a client application’s character set to the database character set on INSERT and UPDATE operations.

- **CONNECT** opens a database, allocates system resources for it, and optionally assigns operational parameters for the database.

All databases must be closed before a program ends. A database can be closed by using DISCONNECT, or by appending the RELEASE option to the final COMMIT or ROLLBACK in a program.

### Declaring a database

Before a database can be opened and used in a program, it must first be declared with **SET DATABASE** to:
Establish a database handle.

Associate the database handle with a database file stored on a local or remote node.

A database handle is a unique, abbreviated alias for an actual database name. Database handles are used in subsequent CONNECT, COMMIT RELEASE, and ROLLBACK RELEASE statements to specify which databases they should affect. Except in dynamic SQL (DSQL) applications, database handles can also be used inside transaction blocks to qualify, or differentiate, table names when two or more open databases contain identically named tables.

Each database handle must be unique among all variables used in a program. Database handles cannot duplicate host-language reserved words, and cannot be InterBase reserved words.

The following statement illustrates a simple database declaration:

EXEC SQL
SET DATABASE DB1 = 'employee.gdb';

This database declaration identifies the database file, employee.gdb, as a database the program uses, and assigns the database a handle, or alias, DB1.

If a program runs in a directory different from the directory that contains the database file, then the file name specification in SET DATABASE must include a full path name, too. For example, the following SET DATABASE declaration specifies the full path to employee.gdb:

EXEC SQL
SET DATABASE DB1 = '/interbase/examples/employee.gdb';

If a program and a database file it uses reside on different hosts, then the file name specification must also include a host name. The following declaration illustrates how a Unix host name is included as part of the database file specification on a TCP/IP network:

EXEC SQL
SET DATABASE DB1 = 'jupiter:/usr/interbase/examples/employee.gdb';

On a Windows network that uses the Netbeui protocol, specify the path as follows:

EXEC SQL
SET DATABASE DB1 = '//venus/C:/Interbase/examples/employee.gdb';
**Declaring multiple databases**

An SQL program, but not a DSQL program, can access multiple databases at the same time. In multi-database programs, database handles are required. A handle is used to:

- Reference individual databases in a multi-database transaction.
- Qualify table names.
- Specify databases to open in CONNECT statements.
- Indicate databases to close with DISCONNECT, COMMIT RELEASE, and ROLLBACK RELEASE.

DSQL programs can access only a single database at a time, so database handle use is restricted to connecting to and disconnecting from a database.

In multi-database programs, each database must be declared in a separate SET DATABASE statement. For example, the following code contains two SET DATABASE statements:

```sql
EXEC SQL
  SET DATABASE DB2 = 'employee2.gdb';
EXEC SQL
  SET DATABASE DB1 = 'employee.gdb';
```

**Using handles for table names**

When the same table name occurs in more than one simultaneously accessed database, a database handle must be used to differentiate one table name from another. The database handle is used as a prefix to table names, and takes the form `handle.table`.

For example, in the following code, the database handles, TEST and EMP, are used to distinguish between two tables, each named EMPLOYEE:

```sql
EXEC SQL
  DECLARE IDMATCH CURSOR FOR
    SELECT TESTNO INTO :matchid FROM TEST.EMPLOYEE
    WHERE TESTNO > 100;
EXEC SQL
  DECLARE EIDMATCH CURSOR FOR
    SELECT EMPNO INTO :empid FROM EMP.EMPLOYEE
    WHERE EMPNO = :matchid;
```
This use of database handles applies only to embedded SQL applications. DSQL applications cannot access multiple databases simultaneously.

**Using handles with operations**

In multi-database programs, database handles *must* be specified in CONNECT statements to identify which databases among several to open and prepare for use in subsequent transactions.

Database handles can also be used with DISCONNECT, COMMIT RELEASE, and ROLLBACK RELEASE to specify a subset of open databases to close.

To open and prepare a database with CONNECT, see “Opening a database” on page 41. To close a database with DISCONNECT, COMMIT RELEASE, or ROLLBACK RELEASE, see “Closing a database” on page 49. To learn more about using database handles in transactions, see “Accessing an open database” on page 48.

**Preprocessing and run time databases**

Normally, each SET DATABASE statement specifies a single database file to associate with a handle. When a program is preprocessed, gpre uses the specified file to validate the program's table and column references. Later, when a user runs the program, the same database file is accessed. Different databases can be specified for preprocessing and run time when necessary.

**Using the COMPILETIME clause**

A program can be designed to run against any one of several identically structured databases. In other cases, the actual database that a program will use at runtime is not available when a program is preprocessed and compiled. In such cases, SET DATABASE can include a COMPILETIME clause to specify a database for gpre to test against during preprocessing. For example, the following SET DATABASE statement declares that employee.gdb is to be used by gpre during preprocessing:

```sql
EXEC SQL
    SET DATABASE EMP = COMPILETIME 'employee.gdb';
```

**Important** The file specification that follows the COMPILETIME keyword must always be a hard-coded, quoted string.
When SET DATABASE uses the COMPILETIME clause, but no RUNTIME clause, and does not specify a different database file specification in a subsequent CONNECT statement, the same database file is used both for preprocessing and run time. To specify different preprocessing and runtime databases with SET DATABASE, use both the COMPILETIME and RUNTIME clauses.

- **Using the RUNTIME clause**

When a database file is specified for use during preprocessing, SET DATABASE can specify a different database to use at run time by including the RUNTIME keyword and a runtime file specification:

```sql
EXEC SQL
    SET DATABASE EMP = COMPILETIME 'employee.gdb'
    RUNTIME 'employee2.gdb';
```

The file specification that follows the RUNTIME keyword can be either a hard-coded, quoted string, or a host-language variable. For example, the following C code fragment prompts the user for a database name, and stores the name in a variable that is used later in SET DATABASE:

```c
. . .
char db_name[125];
. . .
printf("Enter the desired database name, including node and path):
        \n");
gets(db_name);
EXEC SQL
    SET DATABASE EMP = COMPILETIME 'employee.gdb' RUNTIME :db_name;
. . .
```

**Note** Host-language variables in SET DATABASE must be preceded, as always, by a colon.

---

**Controlling SET DATABASE scope**

By default, SET DATABASE creates a handle that is global to all modules in an application. A *global handle* is one that may be referenced in all host-language modules comprising the program. SET DATABASE provides two optional keywords to change the scope of a declaration:

- **STATIC** limits declaration scope to the module containing the SET DATABASE statement. No other program modules can see or use a database handle declared STATIC.
**EXTERN** notifies **gpre** that a **SET DATABASE** statement in a module duplicates a globally-declared database in another module. If the **EXTERN** keyword is used, then another module must contain the actual **SET DATABASE** statement, or an error occurs during compilation.

The **STATIC** keyword is used in a multi-module program to restrict database handle access to the single module where it is declared. The following example illustrates the use of the **STATIC** keyword:

```
EXEC SQL
  SET DATABASE EMP = STATIC 'employee.gdb';
```

The **EXTERN** keyword is used in a multi-module program to signal that **SET DATABASE** in one module is not an actual declaration, but refers to a declaration made in a different module. **gpre** uses this information during preprocessing. The following example illustrates the use of the **EXTERN** keyword:

```
EXEC SQL
  SET DATABASE EMP = EXTERN 'employee.gdb';
```

If an application contains an **EXTERN** reference, then when it is used at run time, the actual **SET DATABASE** declaration must be processed first, and the database connected before other modules can access it.

A single **SET DATABASE** statement can contain either the **STATIC** or **EXTERN** keyword, but not both. A scope declaration in **SET DATABASE** applies to both **COMPILETIME** and **RUNTIME** databases.

### Specifying a connection character set

When a client application connects to a database, it may have its own character set requirements. The server providing database access to the client does not know about these requirements unless the client specifies them. The client application specifies its character set requirement using the **SET NAMES** statement before it connects to the database.

**SET NAMES** specifies the character set the server should use when translating data from the database to the client application. Similarly, when the client sends data to the database, the server translates the data from the client's character set to the database's default character set (or the character set for an individual column if it differs from the database's default character set).

For example, the following statements specify that the client is using the DOS437 character set, then connect to the database:

```
EXEC SQL
```
SET NAMES DOS437;
EXEC SQL
   CONNECT 'europe.gdb' USER 'JAMES' PASSWORD 'U4EEAH';

For more information about character sets, see the Data Definition Guide. For the complete syntax of SET NAMES and CONNECT, see the Language Reference.

Opening a database

After a database is declared, it must be attached with a CONNECT statement before it can be used. CONNECT:

- Allocates system resources for the database.
- Determines if the database file is local, residing on the same host where the application itself is running, or remote, residing on a different host.
- Opens the database and examines it to make sure it is valid.

InterBase provides transparent access to all databases, whether local or remote. If the database structure is invalid, the on-disk structure (ODS) number does not correspond to the one required by InterBase, or if the database is corrupt, InterBase reports an error, and permits no further access.

Optionally, CONNECT can be used to specify:

- A user name and password combination that is checked against the server's security database before allowing the connect to succeed. User names can be up to 31 characters. Passwords are restricted to 8 characters.
- An SQL role name that the user adopts on connection to the database, provided that the user has previously been granted membership in the role. Regardless of role memberships granted, the user belongs to no role unless specified with this ROLE clause. The client can specify at most one role per connection, and cannot switch roles except by reconnecting.
- The size of the database buffer cache to allocate to the application when the default cache size is inappropriate.

Using simple CONNECT statements

In its simplest form, CONNECT requires one or more database parameters, each specifying the name of a database to open. The name of the database can be a:

- Database handle declared in a previous SET DATABASE statement.
Host-language variable.

Hard-coded file name.

Using a database handle

If a program uses SET DATABASE to provide database handles, those handles should be used in subsequent CONNECT statements instead of hard-coded names. For example,

```sql
EXEC SQL
    SET DATABASE DB1 = 'employee.gdb';
EXEC SQL
    SET DATABASE DB2 = 'employee2.gdb';
EXEC SQL
    CONNECT DB1;
EXEC SQL
    CONNECT DB2;
```

There are several advantages to using a database handle with CONNECT:

- Long file specifications can be replaced by shorter, mnemonic handles.
- Handles can be used to qualify table names in multi-database transactions. DSQL applications do not support multi-database transactions.
- Handles can be reassigned to other databases as needed.
- The number of database cache buffers can be specified as an additional CONNECT parameter.

For more information about setting the number of database cache buffers, see “Setting database cache buffers” on page 47.

Using strings or host-language variables

Instead of using a database handle, CONNECT can use a database name supplied at run time. The database name can be supplied as either a host-language variable or a hard-coded, quoted string.

The following C code demonstrates how a program accessing only a single database might implement CONNECT using a file name solicited from a user at run time:

```c
char fname[125];

printf('Enter the desired database name, including node and path):
        \n');
```
OPENING A DATABASE

gets(fname);
.
EXEC SQL
    CONNECT :fname;
.
Tip This technique is especially useful for programs that are designed to work with many identically structured databases, one at a time, such as CAD/CAM or architectural databases.

MULTIPLE DATABASE IMPLEMENTATION

To use a database specified by the user as a host-language variable in a CONNECT statement in multi-database programs, follow these steps:

1. Declare a database handle using the following SET DATABASE syntax:
   
   EXEC SQL
   
   SET DATABASE handle = COMPILETIME ' dbname '

   Here, handle is a hard-coded database handle supplied by the programmer, dbname is a quoted, hard-coded database name used by gpre during preprocessing.

2. Prompt the user for a database to open.

3. Store the database name entered by the user in a host-language variable.

4. Use the handle to open the database, associating the host-language variable with the handle using the following CONNECT syntax:

   EXEC SQL
   
   CONNECT :variable AS handle;

The following C code illustrates these steps:

.

char fname[125];
.
EXEC SQL
    SET DATABASE DB1 = 'employee.gdb';
printf("Enter the desired database name, including node and path):\n\n");
gets(fname);
EXEC SQL
    CONNECT :fname AS DB1;
.
.
EMBEDDED SQL GUIDE
In this example, SET DATABASE provides a hard-coded database file name for preprocessing with gpre. When a user runs the program, the database specified in the variable, fname, is used instead.

**Using a hard-coded database names**

**IN SINGE-DATABASE PROGRAMS**

In a single-database program that omits SET DATABASE, CONNECT must contain a hard-coded, quoted file name in the following format:

```sql
EXEC SQL
  CONNECT '[host[ path ]] filename';
```

*host* is required only if a program and a database file it uses reside on different nodes. Similarly, *path* is required only if the database file does not reside in the current working directory. For example, the following CONNECT statement contains a hard-coded file name that includes both a Unix host name and a path name:

```sql
EXEC SQL
  CONNECT 'valdez:usr/interbase/examples/employee.gdb';
```

*Note* Host syntax is specific to each server platform.

**IMPORTANT** A program that accesses multiple databases cannot use this form of CONNECT.

**IN MULTI-DATABASE PROGRAMS**

A program that accesses multiple databases must declare handles for each of them in separate SET DATABASE statements. These handles must be used in subsequent CONNECT statements to identify specific databases to open:

```sql
  ... 
  EXEC SQL
    SET DATABASE DB1 = 'employee.gdb'; 
  EXEC SQL
    SET DATABASE DB2 = 'employee2.gdb'; 
  EXEC SQL
    CONNECT DB1; 
  EXEC SQL
    CONNECT DB2; 
  ... 
```

Later, when the program closes these databases, the database handles are no longer in use. These handles can be reassigned to other databases by hard-coding a file name in a subsequent CONNECT statement. For example,
OPENING A DATABASE

EXEC SQL
  DISCONNECT DB1, DB2;
EXEC SQL
  CONNECT 'project.gdb' AS DB1;
  
Additional CONNECT syntax

CONNECT supports several formats for opening databases to provide programming flexibility. The following table outlines each possible syntax, provides descriptions and examples, and indicates whether CONNECT can be used in programs that access single or multiple databases:

<table>
<thead>
<tr>
<th>Syntax</th>
<th>Description</th>
<th>Example</th>
<th>Single access</th>
<th>Multiple access</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONNECT 'dbfile';</td>
<td>Opens a single, hard-coded database file, dbfile.</td>
<td>EXEC SQL CONNECT 'employee.gdb';</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>CONNECT handle;</td>
<td>Opens the database file associated with a previously declared database handle. This is the preferred CONNECT syntax.</td>
<td>EXEC SQL CONNECT EMP;</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>CONNECT 'dbfile' AS handle;</td>
<td>Opens a hard-coded database file, dbfile, and assigns a previously declared database handle to it.</td>
<td>EXEC SQL CONNECT 'employee.gdb' AS EMP;</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>CONNECT :varname AS handle;</td>
<td>Opens the database file stored in the host-language variable, varname, and assigns a previously declared database handle to it.</td>
<td>EXEC SQL CONNECT :fname AS EMP;</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

TABLE 3.1 CONNECT syntax summary

For a complete discussion of CONNECT syntax and its uses, see the Language Reference.
CHAPTER 3 WORKING WITH DATABASES

Attaching to multiple databases

CONNECT can attach to multiple databases. To open all databases specified in previous SET DATABASE statements, use either of the following CONNECT syntax options:

```sql
EXEC SQL
  CONNECT ALL;
EXEC SQL
  CONNECT DEFAULT;
```

CONNECT can also attach to a specified list of databases. Separate each database request from others with commas. For example, the following statement opens two databases specified by their handles:

```sql
EXEC SQL
  CONNECT DB1, DB2;
```

The next statement opens two hard-coded database files and also assigns them to previously declared handles:

```sql
EXEC SQL
  CONNECT 'employee.gdb' AS DB1, 'employee2.gdb' AS DB2;
```

**Tip** Opening multiple databases with a single CONNECT is most effective when a program’s database access is simple and clear. In complex programs that open and close several databases, that substitute database names with host-language variables, or that assign multiple handles to the same database, use separate CONNECT statements to make program code easier to read, debug, and modify.

Handling CONNECT errors

The WHENEVER statement should be used to trap and handle runtime errors that occur during database declaration. The following C code fragment illustrates an error-handling routine that displays error messages and ends the program in an orderly fashion:

```c
... 
EXEC SQL
  WHENEVER SQLERROR
    GOTO error_exit;
... 
```
OPENING A DATABASE

: error_exit
  isc_print_sqlerr(sqlcode, status_vector);
EXEC SQL
  DISCONNECT ALL;
  exit(1);

For a complete discussion of SQL error handling, see Chapter 12, “Error Handling and Recovery.”

---

**Setting database cache buffers**

Besides opening a database, CONNECT can set the number of *cache buffers* assigned to a database for that connection. When a program establishes a connection to a database, InterBase allocates system memory to use as a private buffer. The buffers are used to store accessed database pages to speed performance. The number of buffers assigned for a program determine how many simultaneous database pages it can have access to in the memory pool. Buffers remain assigned until a program finishes with a database.

The default number of database cache buffers assigned to a database is 256. This default can be changed either for a specific database or for an entire server.

- Use the *gfix* utility to set a new default cache buffer size for a database. See the *Operations Guide* for more information about setting database buffer size with *gfix*.
- Change the value of DATABASE_CACHE_PAGES in the InterBase configuration file to change the default cache buffer size on a server-wide basis. Use this option with care, since it makes it easy to overuse memory or create unusably small caches.

  ▶ **Setting individual database buffers**

For programs that access or change many rows in many databases, performance can sometimes be improved by increasing the number of buffers. The maximum number of buffers allowed is system dependent.

- Use the CACHE *n* parameter with CONNECT to change the number of buffers assigned to a database for the duration of the connection, where *n* is the number of buffers to reserve. To set the number of buffers for an individual database, place CACHE *n* after the database name. The following CONNECT specifies 500 buffers for the database pointed to by the EMP handle:

```
EXEC SQL
  CONNECT EMP CACHE 500;
```
Note If you specify a buffer size that is less than the smallest one currently in use for the database, the request is ignored.

The next statement opens two databases, TEST and EMP. Because CACHE is not specified for TEST, its buffers default to 256. EMP is opened with the CACHE clause specifying 400 buffers:

```sql
EXEC SQL
   CONNECT TEST, EMP CACHE 400;
```

Specifying buffers for all databases

To specify the same number of buffers for all databases, use CONNECT ALL with the CACHE \( n \) parameter. For example, the following statements connect to two databases, EMP, and EMP2, and allot 400 buffers to each of them:

```sql
. . .
EXEC SQL
   SET DATABASE EMP = 'employee.gdb';
EXEC SQL
   SET DATABASE EMP2 = 'test.gdb';
EXEC SQL
   CONNECT ALL CACHE 400;
. . .
```

The same effect can be achieved by specifying the same amount of cache for individual databases:

```sql
. . .
EXEC SQL
   CONNECT EMP CACHE 400, TEST CACHE 400;
. . .
```

Accessing an open database

Once a database is connected, its tables can be accessed as follows:

- One database can be accessed in a single transaction.
- One database can be accessed in multiple transactions.
- Multiple databases can be accessed in a single transaction.
- Multiple databases can be accessed in multiple transactions.

For general information about using transactions, see Chapter 4, “Working with Transactions.”
**Differentiating table names**

In SQL, using multiple databases in transactions sometimes requires extra precautions to ensure intended behavior. When two or more databases have tables that share the same name, a database handle must be prefixed to those table names to differentiate them from one another in transactions.

A table name differentiated by a database handle takes the form:

\[ \text{handle.table} \]

For example, the following cursor declaration accesses an EMPLOYEE table in TEST, and another EMPLOYEE table in EMP. TEST and EMP are used as prefixes to indicate which EMPLOYEE table should be referenced:

```sql
... EXEC SQL
  DECLARE IDMATCH CURSOR FOR
    SELECT TESTNO INTO :matchid FROM TEST.EMPLOYEE
    WHERE (SELECT EMPNO FROM EMP.EMPLOYEE WHERE EMPNO = TESTNO);
  ...  
```

**Note** DSQL does not support access to multiple databases in a single statement.

---

**Closing a database**

When a program is finished with a database, the database should be closed. In SQL, a database can be closed in either of the following ways:

- Issue a `DISCONNECT` to detach a database and close files.
- Append a `RELEASE` option to a `COMMIT` or `ROLLBACK` to disconnect from a database and close files.

`DISCONNECT`, `COMMIT RELEASE`, and `ROLLBACK RELEASE` perform the following tasks:

- Close open database files.
- Disconnect from remote database connections.
- Release the memory that holds database metadata descriptions and InterBase engine-compiled requests.

**Note** Closing databases with `DISCONNECT` is preferred for compatibility with the SQL-92 standard. Do not close a database until it is no longer needed. Once closed, a database must be reopened, and its resources reallocated, before it can be used again.
With DISCONNECT

To close all open databases by disconnecting from them, use the following DISCONNECT syntax:

EXEC SQL
  DISCONNECT {ALL | DEFAULT};

For example, each of the following statements closes all open databases in a program:

EXEC SQL
  DISCONNECT ALL;
EXEC SQL
  DISCONNECT DEFAULT;

To close specific databases, specify their handles as comma-delimited parameters, using the following syntax:

EXEC SQL
  DISCONNECT handle [, handle ...];

For example, the following statement disconnects from two databases:

EXEC SQL
  DISCONNECT DB1, DB2;

Note A database should not be closed until all transactions are finished with it, or it must be reopened and its resources reallocated.

With COMMIT and ROLLBACK

To close all open databases when you COMMIT or ROLLBACK, use the following syntax:

EXEC SQL
  {COMMIT | ROLLBACK} RELEASE;

For example, the following COMMIT closes all open databases:

EXEC SQL
  COMMIT RELEASE;

To close specific databases, provide their handles as parameters following the RELEASE option with COMMIT or ROLLBACK, using the following syntax:

EXEC SQL
  COMMIT | ROLLBACK RELEASE handle [, handle ...];
In the following example, the ROLLBACK statement closes two databases:

EXEC SQL
    ROLLBACK RELEASE DB1, DB2;
All SQL data definition and data manipulation statements take place within the context of a transaction, a set of SQL statements that works to carry out a single task. This chapter explains how to open, control, and close transactions using the following SQL transaction management statements:
Transaction management statements define the beginning and end of a transaction. They also control its behavior and interaction with other simultaneously running transactions that share access to the same data within and across applications.

There are two types of transactions in InterBase:

- **GDS__TRANS** is a default transaction that InterBase uses when it encounters a statement requiring a transaction without first finding a SET TRANSACTION statement. A default behavior is defined for GDS__TRANS, but it can be changed by starting the default transaction with SET TRANSACTION and specifying alternative behavior as parameters. Treat GDS__TRANS as a global variable of type `isc_tr_handle`.

  **Note** When using the default transaction without explicitly starting it with SET TRANSACTION, applications must be preprocessed without the `gpre -m` switch.

- **Named transactions** are always started with SET TRANSACTION statements. These statements provide unique names for each transaction, and usually include parameters that specify a transaction's behavior.

  Except for naming conventions and use in multi-transaction programs, both the default and named transactions offer the same control over transactions. SET TRANSACTION has optional parameters for specifying access mode, lock resolution, and isolation level.

### Table 4.1 SQL transaction management statements

<table>
<thead>
<tr>
<th>Statement</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>SET TRANSACTION</td>
<td>Starts a transaction, assigns it a name, and specifies its behavior. The following behaviors can be specified:</td>
</tr>
<tr>
<td></td>
<td><strong>Access mode</strong> describes the actions a transaction's statements can perform.</td>
</tr>
<tr>
<td></td>
<td><strong>Lock resolution</strong> describes how a transaction should react if a lock conflict occurs.</td>
</tr>
<tr>
<td></td>
<td><strong>Isolation level</strong> describes the view of the database given a transaction as it relates to actions performed by other simultaneously occurring transactions.</td>
</tr>
<tr>
<td></td>
<td><strong>Table reservation</strong>, an optional list of tables to lock for access at the start of the transaction rather than at the time of explicit reads or writes.</td>
</tr>
<tr>
<td></td>
<td><strong>Database specification</strong>, an optional list limiting the open databases to which a transaction may have access.</td>
</tr>
<tr>
<td>COMMIT</td>
<td>Saves a transaction's changes to the database and ends the transaction.</td>
</tr>
<tr>
<td>ROLLBACK</td>
<td>Undoes a transaction's changes before they have been committed to the database, and ends the transaction.</td>
</tr>
</tbody>
</table>
Starting the default transaction

If a transaction is started without a specified behavior, the following default behavior is used:

READ WRITE WAIT ISOLATION LEVEL SNAPSHOT

The default transaction is especially useful for programs that use only a single transaction. It is automatically started in programs that require a transaction context where none is explicitly provided. It can also be explicitly started in a program with SET TRANSACTION.

To learn more about transaction behavior, see “Starting the default transaction” on page 55.

Starting without SET TRANSACTION

Simple, single transaction programs can omit SET TRANSACTION. The following program fragment issues a SELECT statement without starting a transaction:

```sql
EXEC SQL
  SELECT * FROM CITIES
    WHERE POPULATION > 4000000
    ORDER BY POPULATION, CITY;
```

A programmer need only start the default transaction explicitly in a single transaction program to modify its operating characteristics or when writing a DSQL application that is preprocessed with the `gpre -m` switch.

During preprocessing, when `gpre` encounters a statement, such as SELECT, that requires a transaction context without first finding a SET TRANSACTION statement, it automatically generates a default transaction as long as the `-m` switch is not specified. A default transaction started by `gpre` uses a predefined, or default, behavior that dictates how the transaction interacts with other simultaneous transactions attempting to access the same data.
DSQL programs should be preprocessed with the `gpre -m` switch if they start a transaction through DSQL. In this mode, `gpre` does not generate the default transaction as needed, but instead reports an error if there is no transaction.

For more information about transaction behaviors that can be modified, see “Specifying SET TRANSACTION behavior” on page 60. For more information about using the `gpre -m` switch, see Chapter 14, “Preprocessing, Compiling, and Linking.”

### Starting with SET TRANSACTION

SET TRANSACTION issued without parameters starts the default transaction, GDS__TRANS, with the following default behavior:

- **Access mode**: READ WRITE
- **Lock resolution**: WAIT
- **Isolation level**: ISOLATION LEVEL SNAPSHOT

The following table summarizes these settings:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Setting</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access mode</td>
<td>READ WRITE</td>
<td>Access mode. This transaction can select, insert, update, and delete data.</td>
</tr>
<tr>
<td>Lock resolution</td>
<td>WAIT</td>
<td>Lock resolution. This transaction waits for locked tables and rows to be released to see if it can then update them before reporting a lock conflict.</td>
</tr>
<tr>
<td>Isolation level</td>
<td>ISOLATION LEVEL SNAPSHOT</td>
<td>This transaction receives a stable, unchanging view of the database as it is at the moment the transaction starts; it never sees changes made to the database by other active transactions.</td>
</tr>
</tbody>
</table>

**Note** Explicitly starting the default transaction is good programming practice. It makes a program’s source code easier to understand.

The following statements are equivalent. They both start the default transaction with the default behavior.

```
EXEC SQL
  SET TRANSACTION;
EXEC SQL
  SET TRANSACTION NAME gds__trans READ WRITE WAIT ISOLATION LEVEL SNAPSHOT;
```
To start the default transaction, but change its characteristics, SET TRANSACTION must be used to specify those characteristics that differ from the default. Characteristics that do not differ from the default can be omitted. For example, the following statement starts the default transaction for READ ONLY access, WAIT lock resolution, and ISOLATION LEVEL SNAPSHOT:

```sql
EXEC SQL
    SET TRANSACTION READ ONLY;
```

As this example illustrates, the NAME clause can be omitted when starting the default transaction.

**IMPORTANT** In DSQL, changing the characteristics of the default transaction is accomplished as with PREPARE and EXECUTE in a manner similar to the one described, but the program must be preprocessed using the `gpre -m` switch.

For more information about preprocessing programs with the `-m` switch, see Chapter 14, “Preprocessing, Compiling, and Linking.” For more information about transaction behavior and modification, see “Specifying SET TRANSACTION behavior” on page 60.

---

### Starting a named transaction

A single application can start simultaneous transactions. InterBase extends transaction management and data manipulation statements to support transaction names, unique identifiers that specify which transaction controls a given statement among those transactions that are active.

Transaction names must be used to distinguish one transaction from another in programs that use two or more transactions at a time. Each transaction started while other transactions are active requires a unique name and its own SET TRANSACTION statement. SET TRANSACTION can include optional parameters that modify a transaction's behavior.

There are four steps for using transaction names in a program:

1. Declare a unique host-language variable for each transaction name. In C and C++, transaction names should be declared as long pointers.
2. Initialize each transaction name to zero.
3. Use SET TRANSACTION to start each transaction using an available transaction name.
4. Include the transaction name in subsequent transaction management and data manipulation statements that should be controlled by a specified transaction.
IMPORTANT Using named transactions in dynamic SQL statements is somewhat different. For information about named transactions in DSQL, see “Working with multiple transactions in DSQL” on page 83.

For additional information about creating multiple transaction programs, see “Working with multiple transactions” on page 79.

### Naming transactions

A transaction name is a programmer-supplied variable that distinguishes one transaction from another in SQL statements. If transaction names are not used in SQL statements that control transactions and manipulate data, then those statements operate only on the default transaction, GDS__TRANS.

The following C code declares and initializes two transaction names using the \textit{isc_tr_handle} datatype. It then starts those transactions in SET TRANSACTION statements.

```c
EXEC SQL
BEGIN DECLARE SECTION;
  isc_tr_handle t1, t2; /* declare transaction names */
EXEC SQL
END DECLARE SECTION;

. . .
t1 = t2 = (isc_tr_handle) NULL; /* initialize names to zero */

EXEC SQL
  SET TRANSACTION NAME t1; /* start trans. w. default behavior */
EXEC SQL
  SET TRANSACTION NAME t2; /* start trans2. w. default behavior */
```

Each of these steps is fully described in the following sections.

A transaction name can be included as an optional parameter in any data manipulation and transaction management statement. In multi-transaction programs, omitting a transaction name causes a statement to be executed for the default transaction, GDS__TRANS.

For more information about using transaction names with data manipulation statements, see Chapter 6, “Working with Data.”
Declaring transaction names

Transaction names must be declared before they can be used. A name is declared as a host-language pointer. In C and C++, transaction names should be declared as long pointers.

The following code illustrates how to declare two transaction names:

```sql
EXEC SQL
BEGIN DECLARE SECTION;
isc_tr_handle t1;
isc_tr_handle t2;
EXEC SQL
END DECLARE SECTION;
```

Note In this example, the transaction declaration occurs within an SQL section declaration. While InterBase does not require that host-language variables occur within a section declaration, putting them there guarantees compatibility with other SQL implementations that do require section declarations.

Transaction names are usually declared globally at the module level. If a transaction name is declared locally, ensure that:

- The transaction using the name is completely contained within the function where the name is declared. Include an error-handling routine to roll back transactions when errors occur. ROLLBACK releases a transaction name, and sets its value to NULL.
- The transaction name is not used outside the function where it is declared.

To reference a transaction name declared in another module, provide an external declaration for it. For example, in C, the external declaration for `t1` and `t2` might be as follows:

```sql
EXEC SQL
BEGIN DECLARE SECTION;
extern isc_tr_handle t1, t2;
EXEC SQL
END DECLARE SECTION;
```

Initializing transaction names

Once transaction names are declared, they should be initialized to zero before being used for the first time. The following C code illustrates how to set a starting value for two declared transaction names:

```c
/* initialize transaction names to zero */
t1 = t2 = (isc_tr_handle) NULL;
```
Once a transaction name is declared and initialized, it can be used to:

- Start and name a transaction. Using a transaction name for all transactions except for the default transaction is required if a program runs multiple, simultaneous transactions.
- Specify which transactions control data manipulation statements. Transaction names are required in multi-transaction programs, unless a statement affects only the default transaction.
- Commit or roll back specific transactions in a multi-transaction program.

**Specifying SET TRANSACTION behavior**

Use `SET TRANSACTION` to start a named transaction, and optionally specify its behavior. The syntax for starting a named transaction using default behavior is:

```
SET TRANSACTION NAME name;
```

For a summary of the default behavior for a transaction started without specifying behavior parameters, see table 4.2 on page 56. The following statements are equivalent: they both start the transaction named \( t1 \), using default transaction behavior.

```
EXEC SQL
    SET TRANSACTION NAME t1;
EXEC SQL
    SET TRANSACTION NAME t1 READ WRITE WAIT ISOLATION LEVEL SNAPSHOT;
```
The following table lists the optional SET TRANSACTION parameters for specifying the behavior of the default transaction:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Setting</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access Mode</td>
<td>READ ONLY or READ WRITE</td>
<td>Describes the type of access this transaction is permitted for a table. For more information about access mode, see “Access mode” on page 62.</td>
</tr>
<tr>
<td>Lock Resolution</td>
<td>WAIT or NO WAIT</td>
<td>Specifies what happens when this transaction encounters a locked row during an update or delete. It either waits for the lock to be released so it can attempt to complete its actions, or it returns an immediate lock conflict error message. For more information about lock resolution, see “Lock resolution” on page 69.</td>
</tr>
<tr>
<td>Isolation Level</td>
<td>SNAPSHOT</td>
<td>SNAPSHOT provides a view of the database at the moment this transaction starts, but prevents viewing changes made by other active transactions. SNAPSHOT TABLE STABILITY prevents other transactions from making changes to tables that this transaction is reading and updating, but permits them to read rows in the table. READ COMMITTED reads the most recently committed version of a row during updates and deletions, and allows this transaction to make changes if there is no update conflict with other transactions.</td>
</tr>
<tr>
<td></td>
<td>Table Reservation</td>
<td>Specifies a subset of available tables to lock immediately for this transaction to access.</td>
</tr>
<tr>
<td></td>
<td>Database Specification</td>
<td>Specifies a subset of available databases that this transaction can access; it cannot access any other databases. The purpose of this option is to reduce the amount of system resources used by this transaction. Note: USING is not available in DSQL.</td>
</tr>
</tbody>
</table>

| Table 4.3 | SET TRANSACTION parameters |
Chapter 4: Working with Transactions

The complete syntax of SET TRANSACTION is:

```
EXEC SQL
    SET TRANSACTION [NAME name]
    [READ WRITE| READ ONLY]
    [WAIT | NO WAIT]
    [[ISOLATION LEVEL] [SNAPSHOT [TABLE STABILITY]
    | READ COMMITTED [NO] RECORD_VERSION]]
    [RESERVING <reserving_clause>
    | USING dbhandle [, dbhandle ...]];
<reserving_clause> = table [, table ...]
    [FOR [SHARED | PROTECTED] {READ | WRITE}] [, <reserving_clause>]
```

Transaction options are fully described in the following sections.

- **Access mode**
  
The access mode parameter specifies the type of access a transaction has for the tables it uses. There are two possible settings:

  - **READ ONLY** specifies that a transaction can select data from a table, but cannot insert, update, or delete table data.
  - **READ WRITE** specifies that a transaction can select, insert, update, and delete table data. This is the default setting if none is specified.

  InterBase assumes that most transactions both read and write data. When starting a transaction for reading and writing, READ WRITE can be omitted from SET TRANSACTION statement. For example, the following statements start a transaction, `t1`, for READ WRITE access:

  ```
  EXEC SQL
  SET TRANSACTION NAME t1;
  EXEC SQL
  SET TRANSACTION NAME t1 READ WRITE;
  ```

  **Tip** It is good programming practice to specify a transaction’s access mode, even when it is READ WRITE. It makes an application’s source code easier to read and debug because the program’s intentions are clearly spelled out.

  Start a transaction for READ ONLY access when you only need to read data. READ ONLY must be specified. For example, the following statement starts a transaction, `t1`, for read-only access:

  ```
  EXEC SQL
  SET TRANSACTION NAME t1 READ ONLY;
  ```
Isolation level

The isolation level parameter specifies the control a transaction exercises over table access. It determines the:

- View of a database the transaction can see.
- Table access allowed to this and other simultaneous transactions.

The following table describes the three isolation levels supported by InterBase:

<table>
<thead>
<tr>
<th>Isolation level</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNAPSHOT</td>
<td>Provides a stable, committed view of the database at the time the transaction starts; this is the default isolation level. Other simultaneous transactions can UPDATE and INSERT rows, but this transaction cannot see those changes. For updated rows, this transaction sees versions of those rows as they existed at the start of the transaction. If this transaction attempts to update or delete rows changed by another transaction, an update conflict is reported.</td>
</tr>
<tr>
<td>SNAPSHOT TABLE STABILITY</td>
<td>Provides a transaction sole insert, update, and delete access to the tables it uses. Other simultaneous transactions may still be able to select rows from those tables.</td>
</tr>
<tr>
<td>READ COMMITTED</td>
<td>Enables the transaction to see all committed data in the database, and to update rows updated and committed by other simultaneous transactions without causing lost update problems.</td>
</tr>
</tbody>
</table>

The isolation level for most transactions should be either SNAPSHOT or READ COMMITTED. These levels enable simultaneous transactions to select, insert, update, and delete data in shared databases, and they minimize the chance for lock conflicts. Lock conflicts occur in two situations:

- When a transaction attempts to update a row already updated or deleted by another transaction. A row updated by a transaction is effectively locked for update to all other transactions until the controlling transaction commits or rolls back. READ COMMITTED transactions can read and update rows updated by simultaneous transactions after they commit.

- When a transaction attempts to insert, update, or delete a row in a table locked by another transaction with an isolation level of SNAPSHOT TABLE STABILITY. SNAPSHOT TABLE STABILITY locks entire tables for write access, although concurrent reads by other SNAPSHOT and READ COMMITTED transactions are permitted.
Using SNAPSHOT TABLE STABILITY guarantees that only a single transaction can make changes to tables, but increases the chance of lock conflicts where there are simultaneous transactions attempting to access the same tables. For more information about the likelihood of lock conflicts, see “Isolation level interactions” on page 68.

COMPARING SNAPSHOT, READ COMMITTED, AND SNAPSHOT TABLE STABILITY

There are five classic problems all transaction management statements must address:

- **Lost updates**, which can occur if an update is overwritten by a simultaneous transaction unaware of the last updates made by another transaction.
- **Dirty reads**, which can occur if the system allows one transaction to select uncommitted changes made by another transaction.
- **Non-reproducible reads**, which can occur if one transaction is allowed to update or delete rows that are repeatedly selected by another transaction. READ COMMITTED transactions permit non-reproducible reads by design, since they can see committed deletes made by other transactions.
- **Phantom rows**, which can occur if one transaction is allowed to select some, but not all, new rows written by another transaction. READ COMMITTED transactions do not prevent phantom rows.
- **Update side effects**, which can occur when row values are interdependent, and their dependencies are not adequately protected or enforced by locking, triggers, or integrity constraints. These conflicts occur when two or more simultaneous transactions randomly and repeatedly access and update the same data; such transactions are called *interleaved transactions*. 
Except as noted, all three InterBase isolation levels control these problems. The following table summarizes how a transaction with a particular isolation level controls access to its data for other simultaneous transactions:

<table>
<thead>
<tr>
<th>Problem</th>
<th>SNAPSHOT, READ COMMITTED</th>
<th>SNAPSHOT TABLE STABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lost updates</td>
<td>Other transactions cannot update rows already updated by this transaction.</td>
<td>Other transactions cannot update tables controlled by this transaction.</td>
</tr>
<tr>
<td>Dirty reads</td>
<td>Other SNAPSHOT transactions can only read a previous version of a row updated by this transaction.</td>
<td>Other transactions cannot access tables updated by this transaction.</td>
</tr>
<tr>
<td></td>
<td>Other READ COMMITTED transactions can only read a previous version, or committed updates.</td>
<td></td>
</tr>
<tr>
<td>Non-reproducible</td>
<td>SNAPSHOT and SNAPSHOT TABLE STABILITY transactions can only read versions of rows committed when they started.</td>
<td>SNAPSHOT and SNAPSHOT TABLE STABILITY transactions can only read versions of rows committed when they started.</td>
</tr>
<tr>
<td>reads</td>
<td>READ COMMITTED transactions must expect that reads cannot be reproduced.</td>
<td>Other transactions cannot access tables updated by this transaction.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phantom rows</td>
<td>READ COMMITTED transactions may encounter phantom rows.</td>
<td>Other transactions cannot access tables controlled by this transaction.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Update side effects</td>
<td>Other SNAPSHOT transactions can only read a previous version of a row updated by this transaction.</td>
<td>Other transactions cannot update tables controlled by this transaction.</td>
</tr>
<tr>
<td></td>
<td>Other READ COMMITTED transactions can only read a previous version, or committed updates.</td>
<td>Use triggers and integrity constraints to avoid any problems with interleaved transactions.</td>
</tr>
<tr>
<td></td>
<td>Use triggers and integrity constraints to try to avoid any problems with interleaved transactions.</td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 4.5** InterBase management of classic transaction conflicts

**CHOOSING BETWEEN SNAPSHOT AND READ COMMITTED**

The choice between SNAPSHOT and READ COMMITTED isolation levels depends on an application's needs. SNAPSHOT is the default InterBase isolation level. READ COMMITTED duplicates SNAPSHOT behavior, but can read subsequent changes committed by other transactions. In many cases, using READ COMMITTED reduces data contention.
SNAPSHOT transactions receive a stable view of a database as it exists the moment the transactions start. READ COMMITTED transactions can see the latest committed versions of rows. Both types of transactions can use SELECT statements unless they encounter the following conditions:

- Table locked by SNAPSHOT TABLE STABILITY transaction for UPDATE.
- Uncommitted inserts made by other simultaneous transactions. In this case, a SELECT is allowed, but changes cannot be seen.

READ COMMITTED transactions can read the latest committed version of rows. A SNAPSHOT transaction can read only a prior version of the row as it existed before the update occurred.

SNAPSHOT and READ COMMITTED transactions with READ WRITE access can use INSERT, UPDATE, and DELETE unless they encounter tables locked by SNAPSHOT TABLE STABILITY transactions.

SNAPSHOT transactions cannot update or delete rows previously updated or deleted and then committed by other simultaneous transactions. Attempting to update a row previously updated or deleted by another transaction results in an update conflict error.

A READ COMMITTED READ WRITE transaction can read changes committed by other transactions, and subsequently update those changed rows.

Occasional update conflicts may occur when simultaneous SNAPSHOT and READ COMMITTED transactions attempt to update the same row at the same time. When update conflicts occur, expect the following behavior:

- For mass or searched updates, updates where a single UPDATE modifies multiple rows in a table, all updates are undone on conflict. The UPDATE can be retried. For READ COMMITTED transactions, the NO RECORD_VERSION option can be used to narrow the window between reads and updates or deletes. For more information, see “Starting a transaction with READ COMMITTED isolation level” on page 67.

- For cursor or positioned updates, where rows are retrieved and updated from an active set one row at a time, only a single update is undone. To retry the update, the cursor must be closed, then reopened, and updates resumed at the point of previous conflict.

For more information about UPDATE through cursors, see Chapter 6, “Working with Data.”

STARTING A TRANSACTION WITH SNAPSHOT ISOLATION LEVEL

InterBase assumes that the default isolation level for transactions is SNAPSHOT. Therefore, SNAPSHOT need not be specified in SET TRANSACTION to set the isolation level. For example, the following statements are equivalent. They both start a transaction, **t1**, for READ WRITE access and set isolation level to SNAPSHOT.
EXEC SQL
    SET TRANSACTION NAME t1;
EXEC SQL
    SET TRANSACTION NAME t1 READ WRITE SNAPSHOT;

When an isolation level is specified, it must follow the access and lock resolution modes.

**Tip** It is good programming practice to specify a transaction's isolation level, even when it is SNAPSHOT. It makes an application's source code easier to read and debug because the program's intentions are clearly spelled out.

**STARTING A TRANSACTION WITH READ COMMITTED ISOLATION LEVEL**

To start a READ COMMITTED transaction, the isolation level must be specified. For example, the following statement starts a named transaction, `t1`, for READ WRITE access and sets isolation level to READ COMMITTED:

EXEC SQL
    SET TRANSACTION NAME t1 READ WRITE READ COMMITTED;

Isolation level always follows access mode. If the access mode is omitted, isolation level is the first parameter to follow the transaction name.

READ COMMITTED supports mutually exclusive optional parameters, RECORD_VERSION and NO RECORD_VERSION, which determine the READ COMMITTED behavior when it encounters a row where the latest version of that row is uncommitted:

- **RECORD_VERSION** specifies that the transaction immediately reads the latest committed version of a row, even if a more recent uncommitted version also resides on disk.
- **NO RECORD_VERSION**, the default, specifies that the transaction can only read the latest version of a requested row. If the WAIT lock resolution option is also specified, then the transaction waits until the latest version of a row is committed or rolled back, and retries its read. If the NO WAIT option is specified, the transaction returns an immediate deadlock error.

Because NO RECORD_VERSION is the default behavior, it need not be specified with READ COMMITTED. For example, the following statements are equivalent. They start a named transaction, `t1`, for READ WRITE access and set isolation level to READ COMMITTED NO RECORD_VERSION.

EXEC SQL
    SET TRANSACTION NAME t1 READ WRITE READ COMMITTED;
EXEC SQL
    SET TRANSACTION NAME t1 READ WRITE READ COMMITTED NO RECORD_VERSION;
RECORD_VERSION must always be specified when it is used. For example, the following statement starts a named transaction, t1, for READ WRITE access and sets isolation level to READ COMMITTED RECORD_VERSION:

EXEC SQL
  SET TRANSACTION NAME t1 READ WRITE READ COMMITTED
  RECORD_VERSION;

STARTING A TRANSACTION WITH SNAPSHOT TABLE STABILITY ISOLATION LEVEL

To start a SNAPSHOT TABLE STABILITY transaction, the isolation level must be specified. For example, the following statement starts a named transaction, t1, for READ WRITE access and sets isolation level to SNAPSHOT TABLE STABILITY:

EXEC SQL
  SET TRANSACTION NAME t1 READ WRITE SNAPSHOT TABLE STABILITY;

Isolation level always follows the optional access mode and lock resolution parameters, if they are present.

IMPORTANT Use SNAPSHOT TABLE STABILITY with care. In an environment where multiple transactions share database access, SNAPSHOT TABLE STABILITY greatly increases the likelihood of lock conflicts.

ISOLATION LEVEL INTERACTIONS

To determine the possibility for lock conflicts between two transactions accessing the same database, each transaction's isolation level and access mode must be considered. The following table summarizes possible combinations.

<table>
<thead>
<tr>
<th>SNAPSHOT or READ COMMITTED</th>
<th>SNAPSHOT TABLE STABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPDATE</td>
<td>SELECT</td>
</tr>
<tr>
<td>SNAPSHOT or READ COMMITTED</td>
<td>Some simultaneous updates may conflict</td>
</tr>
<tr>
<td>SELECT</td>
<td>—</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SNAPSHOTTABLE STABILITY</th>
<th>UPDATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPDATE</td>
<td>Always conflicts</td>
</tr>
<tr>
<td>SELECT</td>
<td>Always conflicts</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SNAPSHOTTABLE STABILITY</th>
<th>SELECT</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPDATE</td>
<td>Always conflicts</td>
</tr>
<tr>
<td>SELECT</td>
<td>Always conflicts</td>
</tr>
</tbody>
</table>

| TABLE 4.6 Isolation level Interaction with SELECT and UPDATE |

...
As this table illustrates, SNAPSHOT and READ COMMITTED transactions offer the least chance for conflicts. For example, if \( t1 \) is a SNAPSHOT transaction with READ WRITE access, and \( t2 \) is a READ COMMITTED transaction with READ WRITE access, \( t1 \) and \( t2 \) only conflict when they attempt to update the same rows. If \( t1 \) and \( t2 \) have READ ONLY access, they never conflict with any other transaction.

A SNAPSHOT TABLE STABILITY transaction with READ WRITE access is guaranteed that it alone can update tables, but it conflicts with all other simultaneous transactions except for SNAPSHOT and READ COMMITTED transactions running in READ ONLY mode. A SNAPSHOT TABLE STABILITY transaction with READ ONLY access is compatible with any other read-only transaction, but conflicts with any transaction that attempts to insert, update, or delete data.

**Lock resolution**

The lock resolution parameter determines what happens when a transaction encounters a lock conflict. There are two options:

- **WAIT**, the default, causes the transaction to wait until locked resources are released. Once the locks are released, the transaction retries its operation.
- **NO WAIT** returns a lock conflict error without waiting for locks to be released.

Because **WAIT** is the default lock resolution, you don’t need to specify it in a SET TRANSACTION statement. For example, the following statements are equivalent. They both start a transaction, \( t1 \), for READ WRITE access, **WAIT** lock resolution, and READ COMMITTED isolation level:

```sql
EXEC SQL
    SET TRANSACTION NAME t1 READ WRITE READ COMMITTED;
EXEC SQL
    SET TRANSACTION NAME t1 READ WRITE WAIT READ COMMITTED;
```

To use **NO WAIT**, the lock resolution parameter must be specified. For example, the following statement starts the named transaction, \( t1 \), for READ WRITE access, **NO WAIT** lock resolution, and SNAPSHOT isolation level:

```sql
EXEC SQL
    SET TRANSACTION NAME t1 READ WRITE NO WAIT READ SNAPSHOT;
```

When lock resolution is specified, it follows the optional access mode, and precedes the optional isolation level parameter.

**Tip** It is good programming practice to specify a transaction’s lock resolution, even when it is **WAIT**. It makes an application’s source code easier to read and debug because the program’s intentions are clearly spelled out.
RESERVING clause

The optional RESERVING clause enables transactions to guarantee themselves specific levels of access to a subset of available tables at the expense of other simultaneous transactions. Reservation takes place at the start of the transaction instead of only when data manipulation statements require a particular level of access. RESERVING is only useful in an environment where simultaneous transactions share database access. It has three main purposes:

- To prevent possible deadlocks and update conflicts that can occur if locks are taken only when actually needed (the default behavior).
- To provide for dependency locking, the locking of tables that may be affected by triggers and integrity constraints. While explicit dependency locking is not required, it can assure that update conflicts do not occur because of indirect table conflicts.
- To change the level of shared access for one or more individual tables in a transaction. For example, a READ WRITE SNAPSHOT transaction may need exclusive update rights for a single table, and could use the RESERVING clause to guarantee itself sole write access to the table.

**IMPORTANT** A single SET TRANSACTION statement can contain either a RESERVING or a USING clause, but not both. Use the SET TRANSACTION syntax to reserve tables for a transaction:

```sql
EXEC SQL
SET TRANSACTION [NAME name]
[READ WRITE| READ ONLY]
[WAIT | NO WAIT]
[ [ISOLATION LEVEL] {SNAPSHOT [TABLE STABILITY]}
[| READ COMMITTED [([NO] RECORD_VERSION)]}]
RESERVING <reserving_clause>;

<reserving_clause> = table [, table ...]
[FOR [SHARED | PROTECTED] {READ | WRITE}] [, <reserving_clause>]```
Each table should only appear once in the RESERVING clause. Each table, or a list of tables separated by commas, must be followed by a clause describing the type of reservation requested. The following table lists these reservation options:

<table>
<thead>
<tr>
<th>Reservation option</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROTECTED READ</td>
<td>Prevents other transactions from updating rows. All transactions can select from the table.</td>
</tr>
<tr>
<td>PROTECTED WRITE</td>
<td>Prevents other transactions from updating rows. SNAPSHOT and READ COMMITTED transactions can select from the table, but only this transaction can update rows.</td>
</tr>
<tr>
<td>SHARED READ</td>
<td>Any transaction can select from this table. Any READ WRITE transaction can update this table. This is the most liberal reservation mode.</td>
</tr>
<tr>
<td>SHARED WRITE</td>
<td>Any SNAPSHOT or READ COMMITTED READ WRITE transaction can update this table. Other SNAPSHOT and READ COMMITTED transactions can also select from this table.</td>
</tr>
</tbody>
</table>

The following statement starts a SNAPSHOT transaction, \( t1 \), for READ WRITE access, and reserves a single table for PROTECTED WRITE access:

```
EXEC SQL
   SET TRANSACTION NAME t1 READ WRITE WAIT SNAPSHOT
   RESERVING EMPLOYEE FOR PROTECTED WRITE;
```

The next statement starts a READ COMMITTED transaction, \( t1 \), for READ WRITE access, and reserves two tables, one for SHARED WRITE, and another for PROTECTED READ:

```
EXEC SQL
   SET TRANSACTION NAME t1 READ WRITE WAIT READ COMMITTED
   RESERVING EMPLOYEES FOR SHARED WRITE, EMP_PROJ
   FOR PROTECTED READ;
```

SNAPSHOT and READ COMMITTED transactions use RESERVING to implement more restrictive access to tables for other simultaneous transactions. SNAPSHOT TABLE STABILITY transactions use RESERVING to reduce the likelihood of deadlock in critical situations.
USING clause

Every time a transaction is started, InterBase reserves system resources for each database currently attached for program access. In a multi-transaction, multi-database program, the USING clause can be used to preserve system resources by restricting the number of open databases to which a transaction has access. USING restricts a transaction’s access to tables to a listed subset of all open databases using the following syntax:

```
EXEC SQL
SET TRANSACTION [NAME name]
   [READ WRITE | READ ONLY]
   [WAIT | NO WAIT]
   [[ISOLATION LEVEL] {SNAPSHOT [TABLE STABILITY]
       | READ COMMITTED [[NO] RECORD_VERSION]}
   USING dbhandle> [, dbhandle ...];
```

IMPORTANT A single SET TRANSACTION statement can contain either a USING or a RESERVING clause, but not both.

The following C program fragment opens three databases, test.gdb, research.gdb, and employee.gdb, assigning them to the database handles TEST, RESEARCH, and EMP, respectively. Then it starts the default transaction and restricts its access to TEST and EMP:

```
EXEC SQL
SET DATABASE ATLAS = 'test.gdb';
EXEC SQL
SET DATABASE RESEARCH = 'research.gdb';
EXEC SQL
SET DATABASE EMP = 'employee.gdb';
EXEC SQL
CONNECT TEST, RESEARCH, EMP; /* Open all databases */
EXEC SQL
SET TRANSACTION USING TEST, EMP;
```

Using transaction names in data statements

Once named transactions are started, use their names in INSERT, UPDATE, DELETE, and OPEN statements to specify which transaction controls the statement. For example, the following C code fragment declares two transaction handles, mytrans1, and mytrans2, initializes them to zero, starts the transactions, and then uses the transaction names to qualify the data manipulation statements that follow:
EXEC SQL
BEGIN DECLARE SECTION;
  long *mytrans1, *mytrans2;
  char city[26];
EXEC SQL
END DECLARE SECTION;
mytrans1 = 0L;
mytrans2 = 0L;
EXEC SQL
SET DATABASE ATLAS = 'atlas.gdb';
EXEC SQL
CONNECT;
EXEC SQL
DECLARE CITYLIST CURSOR FOR
  SELECT CITY FROM CITIES
  WHERE COUNTRY = 'Mexico';
EXEC SQL
SET TRANSACTION NAME mytrans1;
EXEC SQL
SET TRANSACTION mytrans2 READ ONLY READ COMMITTED;
EXEC SQL
printf('Mexican city to add to database: ');
gets(city);
EXEC SQL
INSERT TRANSACTION mytrans1 INTO CITIES (CITY, COUNTRY)
VALUES :city, 'Mexico';
EXEC SQL
COMMIT mytrans1;
EXEC SQL
OPEN TRANSACTION mytrans2 CITYLIST;
EXEC SQL
FETCH CITYLIST INTO :city;
while (!SQLCODE)
{
  printf("%s\n", city);
  EXEC SQL
    FETCH CITYLIST INTO :city;
}
EXEC SQL
CLOSE CITYLIST;
EXEC SQL
  COMMIT;
EXEC SQL
  DISCONNECT;
.

As this example illustrates, a transaction name cannot appear in a DECLARE CURSOR statement. To use a name with a cursor declaration, include the transaction name in the cursor's OPEN statement. The transaction name is not required in subsequent FETCH and CLOSE statements for that cursor.

Note The DSQL EXECUTE and EXECUTE IMMEDIATE statements also support transaction names.

For more information about using transaction names with data manipulation statements, see Chapter 6, “Working with Data.” For more information about transaction names and the COMMIT statement, see “Using COMMIT” on page 75. For more information about using transaction names with DSQL statements, see “Working with multiple transactions in DSQL” on page 83.

## Ending a transaction

When a transaction's tasks are complete, or an error prevents a transaction from completing, the transaction must be ended to set the database to a consistent state. There are two statements that end transactions:

- COMMIT makes a transaction's changes permanent in the database. It signals that a transaction completed all its actions successfully.
- ROLLBACK undoes a transaction's changes, returning the database to its previous state, before the transaction started. ROLLBACK is typically used when one or more errors occur that prevent a transaction from completing successfully.

Both COMMIT and ROLLBACK close the record streams associated with the transaction, reinitialize the transaction name to zero, and release system resources allocated for the transaction. Freed system resources are available for subsequent use by any application or program.

COMMIT and ROLLBACK have additional benefits. They clearly indicate program logic and intention, make a program easier to understand, and most importantly, assure that a transaction's changes are handled as intended by the programmer.
ROLLBACK is frequently used inside error-handling routines to clean up transactions when errors occur. It can also be used to roll back a partially completed transaction prior to retrying it, and it can be used to restore a database to its prior state if a program encounters an unrecoverable error.

**IMPORTANT** If the program ends before a transaction ends, a transaction is automatically rolled back, but databases are not closed. If a program ends without closing the database, data loss or corruption is possible. Therefore, open databases should always be closed by issuing explicit DISCONNECT, COMMIT RELEASE, or ROLLBACK RELEASE statements.

For more information about DISCONNECT, COMMIT RELEASE, and ROLLBACK RELEASE, see Chapter 3, “Working with Databases.”

**Using COMMIT**

Use COMMIT to write transaction changes permanently to a database. COMMIT closes the record streams associated with the transaction, resets the transaction name to zero, and frees system resources assigned to the transaction for other uses. The complete syntax for COMMIT is:

```sql
EXEC SQL
  COMMIT [TRANSACTION name] [RETAIN [SNAPSHOT] | RELEASE dbhandle
[ , dbhandle ...]]
```

For example, the following C code fragment contains a complete transaction. It gives all employees who have worked since December 31, 1992, a 4.3% cost-of-living salary increase. If all qualified employee records are successfully updated, the transaction is committed, and the changes are actually applied to the database.

```c
... EXEC SQL
  SET TRANSACTION SNAPSHOT TABLE STABILITY;
EXEC SQL
  UPDATE EMPLOYEE
    SET SALARY = SALARY * 1.043
    WHERE HIRE_DATE < '1-JAN-1993';
EXEC SQL
  COMMIT;
...```

By default, COMMIT affects only the default transaction, GDS__TRANS. To commit another transaction, use its transaction name as a parameter to COMMIT.
Tip Even READ ONLY transactions that do not change a database should be ended with a COMMIT rather than ROLLBACK. The database is not changed, but the overhead required to start subsequent transactions is greatly reduced.

Specifying transaction names

To commit changes for transactions other than the default transaction, specify a transaction name as a COMMIT parameter. For example, the following C code fragment starts two transactions using names, and commits them:

```
EXEC SQL
    BEGIN DECLARE SECTION;
        isc_tr_handle TR1, TR2;
    EXEC SQL
    END DECLARE SECTION;
TR1 = (isc_tr_handle) NULL;
TR2 = (isc_tr_handle) NULL;
EXEC SQL
    SET TRANSACTION NAME TR1;
EXEC SQL
    SET TRANSACTION NAME TR2;
    /* do actual processing here */
EXEC SQL
    COMMIT TRANSACTION TR1;
EXEC SQL
    COMMIT TRANSACTION TR2;
```

Important In multi-transaction programs, transaction names must always be specified for COMMIT except when committing the default transaction.

Committing without freeing a transaction

To write transaction changes to the database without releasing the current transaction snapshot, use the RETAIN option with COMMIT. The COMMIT RETAIN statement commits your work and opens a new transaction, preserving the old transaction’s snapshot. In a busy multi-user environment, retaining the snapshot speeds up processing and uses fewer system resources than closing and starting a new transaction for each action. The disadvantage of using COMMIT RETAIN is that you do not see the pending transactions of other users.
The syntax for the RETAIN option is as follows:

```sql
EXEC SQL
    COMMIT [TRANSACTION name] RETAIN [SNAPSHOT];
```

**Tip** Developers who use Borland tools such as Delphi use this feature by specifying “soft commits” in the BDE configuration.

For example, the following C code fragment updates the POPULATION column by user-specified amounts for cities in the CITIES table that are in a country also specified by the user. Each time a qualified row is updated, a COMMIT with the RETAIN option is issued, preserving the current cursor status and system resources.

```c
EXEC SQL
    BEGIN DECLARE SECTION;
    char country[26], city[26], asciimult[10];
    int multiplier;
    long pop;
EXEC SQL
    END DECLARE SECTION;
EXEC SQL
    BEGIN;
EXEC SQL
    DECLARE CHANGEPOP CURSOR FOR
        SELECT CITY, POPULATION
        FROM CITIES
        WHERE COUNTRY = :country;
EXEC SQL
    printf("Enter country with city populations needing adjustment: ");
EXEC SQL
    gets(country);
EXEC SQL
    SET TRANSACTION;
EXEC SQL
    OPEN CHANGEPOP;
EXEC SQL
    FETCH CHANGEPOP INTO :city, :pop;
EXEC SQL
    while(!SQLCODE)
    {
        printf("City: %s Population: %ld\n", city, pop);
        printf("\nPercent change (100% to -100%: ");
        gets(asciimult);
        multiplier = atoi(asciimult);
EXEC SQL
    }
EXEC SQL
```
UPDATE CITIES
    SET POPULATION = POPULATION * (1 + :multiplier / 100)
    WHERE CURRENT OF CHANGEPOP;
EXEC SQL
    COMMIT RETAIN; /* commit changes, save current state */
EXEC SQL
    FETCH CHANGEPOP INTO :city, :pop;
if (SQLCODE && (SQLCODE != 100))
{
    isc_print_sqlerror(SQLCODE, isc_$status);
    EXEC SQL
        ROLLBACK;
    EXEC SQL
        DISCONNECT;
    exit(1);
}
EXEC SQL
    COMMIT;
EXEC SQL
    DISCONNECT;
}

**Note** If you execute a ROLLBACK after a COMMIT RETAIN, it rolls back only updates and writes that occurred after the COMMIT RETAIN.

**IMPORTANT** In multi-transaction programs, a transaction name *must* be specified for COMMIT RETAIN, except when retaining the state of the default transaction. For more information about transaction names, see “**Naming transactions** on page 58.”

---

**Using ROLLBACK**

Use ROLLBACK to restore the database to its condition prior to the start of the transaction. ROLLBACK also closes the record streams associated with the transaction, resets the transaction name to zero, and frees system resources assigned to the transaction for other uses. ROLLBACK typically appears in error-handling routines. The syntax for ROLLBACK is:

```
EXEC SQL
    ROLLBACK [TRANSACTION name] [RELEASE [dbhandle [, dbhandle ...]]];
```
For example, the following C code fragment contains a complete transaction that gives all employees who have worked since December 31, 1992, a 4.3% cost-of-living salary adjustment. If all qualified employee records are successfully updated, the transaction is committed, and the changes are actually applied to the database. If an error occurs, all changes made by the transaction are undone, and the database is restored to its condition prior to the start of the transaction.

```c
EXEC SQL
    SET TRANSACTION SNAPSHOT TABLE STABILITY;
EXEC SQL
    UPDATE EMPLOYEES
        SET SALARY = SALARY * 1.043
        WHERE HIRE_DATE < '1-JAN-1993';
if (SQLCODE && (SQLCODE != 100))
{
    isc_print_sqlerror(SQLCODE, isc_$status);
    EXEC SQL
        ROLLBACK;
    EXEC SQL
        DISCONNECT;
    exit(1);
}
EXEC SQL
    COMMIT;
EXEC SQL
    DISCONNECT;
``` . . .

By default, ROLLBACK affects only the default transaction, GDS__TRANS. To roll back other transactions, use their transaction names as parameters to ROLLBACK.

---

**Working with multiple transactions**

Because InterBase provides support for transaction names, a program can use as many transactions at once as necessary to carry out its work. Each simultaneous transaction in a program requires its own name. A transaction's name distinguishes it from other active transactions. The name can also be used in data manipulation and transaction management statements to specify which transaction controls the statement. For more information about declaring and using transaction names, see "Starting a named transaction" on page 57.
There are four steps for using named transactions in a program:

1. Declare a unique host-language variable for each transaction name.
2. Initialize each transaction variable to zero.
3. Use SET TRANSACTION to start each transaction using an available transaction name.
4. Use the transaction names as parameters in subsequent transaction management and data manipulation statements that should be controlled by a specified transaction.

**The default transaction**

In multi-transaction programs, it is good programming practice to supply a transaction name for every transaction a program defines. One transaction in a multi-transaction program can be the default transaction, GDS__TRANS. When the default transaction is used in multi-transaction programs, it, too, should be started explicitly and referenced by name in data manipulation statements.

If the transaction name is omitted from a transaction management or data manipulation statement, InterBase assumes the statement affects the default transaction. If the default transaction has not been explicitly started with a SET TRANSACTION statement, gpre inserts a statement during preprocessing to start it.

**IMPORTANT** DSQL programs must be preprocessed with the `gpre -m` switch. In this mode, gpre does not generate the default transaction automatically, but instead reports an error. DSQL programs require that all transactions be explicitly started.

**Using cursors**

DECLARE CURSOR does not support transaction names. Instead, to associate a named transaction with a cursor, include the transaction name as an optional parameter in the cursor's OPEN statement. A cursor can only be associated with a single transaction. For example, the following statements declare a cursor, and open it, associating it with the transaction, T1:

```sql
EXEC SQL
   DECLARE S CURSOR FOR
       SELECT COUNTRY, CUST_NO, SUM(QTY_ORDERED)
       FROM SALES
```
GROUP BY CUST_NO
WHERE COUNTRY = 'Mexico';
EXEC SQL
SET TRANSACTION T1 READ ONLY READ COMMITTED;
...
EXEC SQL
OPEN TRANSACTION T1 S;
...

An OPEN statement without the optional transaction name parameter operates under control of the default transaction, GDS_TRANS.

Once a named transaction is associated with a cursor, subsequent cursor statements automatically operate under control of that transaction. Therefore, it does not support a transaction name parameter. For example, the following statements illustrate a FETCH and CLOSE for the S cursor after it is associated with the named transaction, t2:

EXEC SQL
OPEN TRANSACTION t2 S;
EXEC SQL
FETCH S INTO :country, :cust_no, :qty;
while (!SQLCODE)
{
    printf("%s %d %d\n", country, cust_no, qty);
    EXEC SQL
    FETCH S INTO :country, :cust_no, :qty;
}
EXEC SQL
CLOSE S;
...

Multiple cursors can be controlled by a single transaction, or each transaction can control a single cursor according to a program’s needs.

---

**A multi-transaction example**

The following C code illustrates the steps required to create a simple multi-transaction program. It declares two transaction handles, *mytrans1*, and *mytrans2*, initializes them to zero, starts the transactions, and then uses the transaction names to qualify the data manipulation statements that follow. It also illustrates the use of a cursor with a named transaction.

...
EXEC SQL
   BEGIN DECLARE SECTION;
   long *mytrans1 = 0L, *mytrans2 = 0L;
   char city[26];
EXEC SQL
   END DECLARE SECTION;
...
EXEC SQL
   DECLARE CITYLIST CURSOR FOR
   SELECT CITY FROM CITIES
      WHERE COUNTRY = 'Mexico';
EXEC SQL
   SET TRANSACTION NAME mytrans1;
EXEC SQL
   SET TRANSACTION mytrans2 READ ONLY READ COMMITTED;
...
printf("Mexican city to add to database: ");
gets(city);
EXEC SQL
   INSERT TRANSACTION mytrans1 INTO CITIES
      VALUES :city, 'Mexico', NULL, NULL, NULL, NULL;
EXEC SQL
   COMMIT mytrans1;
EXEC SQL
   OPEN TRANSACTION mytrans2 CITYLIST;
EXEC SQL
   FETCH CITYLIST INTO :city;
while (!SQLCODE)
{
   printf("%s
", city);
   EXEC SQL
      FETCH CITYLIST INTO :city;
}
EXEC SQL
   CLOSE CITYLIST;
EXEC SQL
   COMMIT mytrans2;
EXEC SQL
   DISCONNECT
...
Working with multiple transactions in DSQL

In InterBase, DSQL applications can also use multiple transactions, but with the following limitations:

- Programs must be preprocessed with the `gpre -m` switch.
- Transaction names must be declared statically. They cannot be defined through user-modified host variables at run time.
- Transaction names must be initialized to zero before appearing in DSQL statements.
- All transactions must be started with explicit `SET TRANSACTION` statements.
- No data definition language (DDL) can be used in the context of a named transaction in an embedded program; DDL must always occur in the context of the default transaction, `GDS__TRANS`.
- As long as a transaction name parameter is not specified with a `SET TRANSACTION` statement, it can follow a `PREPARE` statement to modify the behavior of a subsequently named transaction in an `EXECUTE` or `EXECUTE IMMEDIATE` statement. This enables a user to modify transaction behaviors at run time.

Transaction names are fixed for all InterBase programs during preprocessing, and cannot be dynamically assigned. A user can still modify DSQL transaction behavior at run time. It is up to the programmer to anticipate possible transaction behavior modification and plan for it. The following section describes how users can modify transaction behavior.

Modifying transaction behavior with "?"

The number and name of transactions available to a DSQL program is fixed when the program is preprocessed with `gpre`, the InterBase preprocessor. The programmer determines both the named transactions that control each DSQL statement in a program, and the default behavior of those transactions. A user can change a named transaction's behavior at run time.

In DSQL programs, a user enters an SQL statement into a host-language string variable, and then the host variable is processed in a `PREPARE` statement or `EXECUTE IMMEDIATE` statement.

**PREPARE**

- Checks the statement in the variable for errors
- Loads the statement into an XSQLDA for a subsequent `EXECUTE` statement
EXECUTE IMMEDIATE

- Checks the statement for errors
- Loads the statement into the XSQLDA
- Executes the statement

Both EXECUTE and EXECUTE IMMEDIATE operate within the context of a programmer-specified transaction, which can be a named transaction. If the transaction name is omitted, these statements are controlled by the default transaction, GDS__TRANS.

You can modify the transaction behavior for an EXECUTE and EXECUTE IMMEDIATE statement by:

- Enabling a user to enter a SET TRANSACTION statement into a host variable
- Executing the SET TRANSACTION statement before the EXECUTE or EXECUTE IMMEDIATE whose transaction context should be modified

In this context, a SET TRANSACTION statement changes the behavior of the next named or default transaction until another SET TRANSACTION occurs.

The following C code fragment provides the user the option of specifying a new transaction behavior, applies the behavior change, executes the next user statement in the context of that changed transaction, then restores the transaction's original behavior.

```
EXEC SQL
BEGIN DECLARE SECTION;
    char usertrans[512], query[1024];
    char deftrans[] = {"SET TRANSACTION READ WRITE WAIT SNAPSHOT"};
EXEC SQL
END DECLARE SECTION;

. . .
printf("Enter SQL statement: ");
gets(query);
printf("Change transaction behavior (Y/N)? ");
gets(usertrans);
if (usertrans[0] == "Y" || usertrans[0] == "y")
{
    printf("Enter "SET TRANSACTION" and desired behavior: ");
    gets(usertrans);
    EXEC SQL
    COMMIT usertrans;
    EXEC SQL
    EXECUTE IMMEDIATE usertrans;
}
else
{
    EXEC SQL
    EXECUTE IMMEDIATE deftrans;
}
EXEC SQL
    EXECUTE IMMEDIATE query;
EXEC SQL
    EXECUTE IMMEDIATE deftrans;
...

**IMPORTANT** As this example illustrates, you must commit or roll back any previous transactions before you can execute SET TRANSACTION.
This chapter discusses how to create, modify, and delete databases, tables, views, and indexes in SQL applications. A database's tables, views, and indexes make up most of its underlying structure, or metadata.

**IMPORTANT** The discussion in this chapter applies equally to dynamic SQL (DSQL) applications, except that users enter DSQL data definition statements at run time, and do not preface those statements with EXEC SQL.
The preferred method for creating, modifying, and deleting metadata is through the InterBase interactive SQL tool, isql, but in some instances, it may be necessary or desirable to embed some data definition capabilities in an SQL application. Both SQL and DSQL applications can use the following subset of data definition statements:

<table>
<thead>
<tr>
<th>CREATE statement</th>
<th>ALTER statement</th>
<th>DROP statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>CREATE DATABASE</td>
<td>ALTER DATABASE</td>
<td>—</td>
</tr>
<tr>
<td>CREATE DOMAIN</td>
<td>ALTER DOMAIN</td>
<td>DROP DOMAIN</td>
</tr>
<tr>
<td>CREATE GENERATOR</td>
<td>SET GENERATOR</td>
<td>—</td>
</tr>
<tr>
<td>CREATE INDEX</td>
<td>ALTER INDEX</td>
<td>DROP INDEX</td>
</tr>
<tr>
<td>CREATE SHADOW</td>
<td>ALTER SHADOW</td>
<td>DROP SHADOW</td>
</tr>
<tr>
<td>CREATE TABLE</td>
<td>ALTER TABLE</td>
<td>DROP TABLE</td>
</tr>
<tr>
<td>CREATE VIEW</td>
<td>—</td>
<td>DROP VIEW</td>
</tr>
<tr>
<td>DECLARE EXTERNAL</td>
<td>—</td>
<td>DROP EXTERNAL</td>
</tr>
<tr>
<td>DECLARE FILTER</td>
<td>—</td>
<td>DROP FILTER</td>
</tr>
</tbody>
</table>

**TABLE 5.1 Data definition statements supported for embedded applications**

DSQL also supports creating, altering, and dropping stored procedures, triggers, and exceptions. DSQL is especially powerful for data definition because it enables users to enter any supported data definition statement at run time. For example, isql itself is a DSQL application. For more information about using isql to define stored procedures, triggers, and exceptions, see the *Data Definition Guide*. For a complete discussion of DSQL programming, see *Chapter 13, “Using Dynamic SQL.”*

### Creating metadata

SQL data definition statements are used in applications the sole purpose of which is to create or modify databases or tables. Typically the expectation is that these applications will be used only once by any given user, then discarded, or saved for later modification by a database designer who can read the program code as a record of a database’s structure. If data definition changes must be made, editing a copy of existing code is easier than starting over.

**Note** Use the InterBase interactive SQL tool, isql, to create and alter data definitions whenever possible. For more information about isql, see the *Operations Guide*.
The SQL CREATE statement is used to make new databases, domains, tables, views, or indexes. A COMMIT statement must follow every CREATE so that subsequent CREATE statements can use previously defined metadata upon which they may rely. For example, domain definitions must be committed before the domain can be referenced in subsequent table definitions.

**IMPORTANT** Applications that mix data definition and data manipulation must be preprocessed using the `gpre-m` switch. Such applications must explicitly start every transaction with SET TRANSACTION.

---

### Creating a database

CREATE DATABASE establishes a new database and its system tables, tables that describe the internal structure of the database. InterBase uses the system tables whenever an application accesses a database. SQL programs can read the data in most of these tables just like any user-created table.

In its most elementary form, the syntax for CREATE DATABASE is:

```sql
EXEC SQL
  CREATE DATABASE '<filespec>';
```

CREATE DATABASE must appear before any other CREATE statements. It requires one parameter, the name of a database to create. For example, the following statement creates a database named `employee.gdb`:

```sql
EXEC SQL
  CREATE DATABASE 'employee.gdb';
```

**Note** The database name can include a full file specification, including both host or node names, and a directory path to the location where the database file should be created. For information about file specifications for a particular operating system, see the operating system manuals.

**IMPORTANT** Although InterBase enables access to remote databases, you should always create a database directly on the machine where it is to reside.

#### Optional parameters

There are optional parameters for CREATE DATABASE. For example, when an application running on a client attempts to connect to an InterBase server in order to create a database, it may be expected to provide USER and PASSWORD parameters before the connection is established. Other parameters specify the database page size, the number and size of multi-file databases, and the default character set for the database.
For a complete discussion of all CREATE DATABASE parameters, see the Data Definition Guide. For the complete syntax of CREATE DATABASE, see the Language Reference.

IMPORTANT An application that creates a database must be preprocessed with the gpre -m switch. It must also create at least one table. If a database is created without a table, it cannot be successfully opened by another program. Applications that perform both data definition and data manipulation must declare tables with DECLARE TABLE before creating and populating them. For more information about table creation, see “Creating a table” on page 91.

Specifying a default character set

A database’s default character set designation specifies the character set the server uses to transliterate and store CHAR, VARCHAR, and text Blob data in the database when no other character set information is provided. A default character set should always be specified for a database when it is created with CREATE DATABASE.

To specify a default character set, use the DEFAULT CHARACTER SET clause of CREATE DATABASE. For example, the following statement creates a database that uses the ISO8859_1 character set:

```sql
EXEC SQL
CREATE DATABASE 'europe.gdb' DEFAULT CHARACTER SET ISO8859_1;
```

If you do not specify a character set, the character set defaults to NONE. Using character set NONE means that there is no character set assumption for columns; data is stored and retrieved just as you originally entered it. You can load any character set into a column defined with NONE, but you cannot later move that data into another column that has been defined with a different character set. In this case, no transliteration is performed between the source and destination character sets, and errors may occur during assignment.

For a complete description of the DEFAULT CHARACTER SET clause and a list of the character sets supported by InterBase, see the Data Definition Guide.

Creating a domain

CREATE DOMAIN creates a column definition that is global to the database, and that can be used to define columns in subsequent CREATE TABLE statements. CREATE DOMAIN is especially useful when many tables in a database contain identical column definitions. For example, in an employee database, several tables might define columns for employees’ first and last names.

At its simplest, the syntax for CREATE DOMAIN is:
EXEC SQL
CREATE DOMAIN name AS <datatype>;

The following statements create two domains, FIRSTNAME, and LASTNAME.
EXEC SQL
CREATE DOMAIN FIRSTNAME AS VARCHAR(15);
EXEC SQL
CREATE DOMAIN LASTNAME AS VARCHAR(20);
EXEC SQL
COMMIT;

Once a domain is defined and committed, it can be used in CREATE TABLE statements to
define columns. For example, the following CREATE TABLE fragment illustrates how the
FIRSTNAME and LASTNAME domains can be used in place of column definitions in the
EMPLOYEE table definition.
EXEC SQL
CREATE TABLE EMPLOYEE
(
    . . .
    FIRST_NAME FIRSTNAME NOT NULL,
    LAST_NAME LASTNAME NOT NULL;
    . . .
);

A domain definition can also specify a default value, a NOT NULL attribute, a CHECK
constraint that limits inserts and updates to a range of values, a character set, and a
collation order.

For more information about creating domains and using them during table creation, see
the Data Definition Guide. For the complete syntax of CREATE DOMAIN, see the Language
Reference.

---

Creating a table

The CREATE TABLE statement defines a new database table and the columns and integrity
constraints within that table. Each column can include a character set specification and
a collation order specification. CREATE TABLE also automatically imposes a default SQL
security scheme on the table. The person who creates a table becomes its owner. A table’s
owner is assigned all privileges for it, including the right to grant privileges to other users.

A table can be created only for a database that already exists. At its simplest, the syntax
for CREATE TABLE is as follows:
EXEC SQL
CREATE TABLE name (col_def | table_constraint
[, col_def | table_constraint ...]);

col_def defines a column using the following syntax:

col {<datatype> | COMPUTED [BY] (<expr>) | domain}
<col_constraint> COLLATE collation

col must be a column name unique within the table definition.

datatype specifies the SQL datatype to use for column entries. COMPUTED BY can be used
to define a column whose value is computed from an expression when the column is
accessed at run time.

col_constraint is an optional integrity constraint that applies only to the associated
column.

tableconstraint is an optional integrity constraint that applies to an entire table.

Integrity constraints ensure that data entered in a table meets specific requirements, to
specify that data entered in a table or column is unique, or to enforce referential integrity
with other tables in the database.

The following code fragment contains SQL statements that create a database,
employee.gdb, and create a table, EMPLOYEE_PROJECT, with three columns, EMP_NO,
PROJ_ID, and DUTIES:

EXEC SQL
CREATE DATABASE 'employee.gdb';
EXEC SQL
CREATE TABLE EMPLOYEE_PROJECT
(
  EMP_NO SMALLINT NOT NULL,
  PROJ_ID CHAR(5) NOT NULL,
  DUTIES Blob SUBTYPE 1 SEGMENT SIZE 240
);
EXEC SQL
COMMIT;

An application can create multiple tables, but duplicating an existing table name is not
permitted.

For more information about SQL datatypes and integrity constraints, see the Data
Definition Guide. For more information about CREATE TABLE syntax, see the Language
Reference. For more information about changing or assigning table privileges, see the
security chapter in the Data Definition Guide.
Creating a computed column

A computed column is one whose value is calculated when the column is accessed at run time. The value can be derived from any valid SQL expression that results in a single, non-array value.

To create a computed column, use the following column declaration syntax in CREATE TABLE:

```sql
col COMPUTED [BY] (<expr>)
```

The expression can reference previously defined columns in the table. For example, the following statement creates a computed column, FULL_NAME, by concatenating two other columns, LAST_NAME, and FIRST_NAME:

```sql
EXEC SQL
    CREATE TABLE EMPLOYEE
    (
        . . .
        FIRST_NAME VARCHAR(10) NOT NULL,
        LAST_NAME VARCHAR(15) NOT NULL,
        . . .
        FULL_NAME COMPUTED BY (LAST_NAME || ', ' || FIRST_NAME)
    )
;
```

For more information about COMPUTED BY, see the Data Definition Guide.

Declaring and creating a table

In programs that mix data definition and data manipulation, the DECLARE TABLE statement must be used to describe a table’s structure to the InterBase preprocessor, gpre, before that table can be created. During preprocessing, if gpre encounters a DECLARE TABLE statement, it stores the table’s description for later reference. When gpre encounters a CREATE TABLE statement for the previously declared table, it verifies that the column descriptions in the CREATE statement match those in the DECLARE statement. If they do not match, gpre reports the errors and cancels preprocessing so that the error can be fixed.

When used, DECLARE TABLE must come before the CREATE TABLE statement it describes. For example, the following code fragment declares a table, EMPLOYEE_PROJ, then creates it:

```sql
EXEC SQL
    DECLARE EMPLOYEE_PROJECT TABLE
    (
        EMP_NO SMALLINT,
        PROJ_ID CHAR(5),
        DUTIES Blob(240, 1)
    )
;
For more information about DECLARE TABLE, see the Language Reference.

Creating a view

A view is a virtual table that is based on a subset of one or more actual tables in a database. Views are used to:

- Restrict user access to data by presenting only a subset of available data.
- Rearrange and present data from two or more tables in a manner especially useful to the program.

Unlike a table, a view is not stored in the database as raw data. Instead, when a view is created, the definition of the view is stored in the database. When a program uses the view, InterBase reads the view definition and quickly generates the output as if it were a table.

To make a view, use the following CREATE VIEW syntax:

```
EXEC SQL
 CREATE VIEW name [(view_col [, view_col ...)] AS 
  <select> [WITH CHECK OPTION];
```

The name of the view, `name`, must be unique within the database.

To give each column displayed in the view its own name, independent of its column name in an underlying table, enclose a list of `view_col` parameters in parentheses. Each column of data returned by the view's `SELECT` statement is assigned sequentially to a corresponding view column name. If a list of view column names is omitted, column names are assigned directly from the underlying table.

Listing independent names for columns in a view ensures that the appearance of a view does not change if its underlying table structures are modified.
Note A view column name must be provided for each column of data returned by the view’s SELECT statement, or else no view column names should be specified.

The select clause is a standard SELECT statement that specifies the selection criteria for rows to include in the view. A SELECT in a view cannot include an ORDER BY clause. In DSQL, it cannot include a UNION clause.

The optional WITH CHECK OPTION restricts inserts, updates, and deletes in a view that can be updated.

To create a read-only view, a view’s creator must have SELECT privilege for the table or tables underlying the view. To create a view for update requires ALL privilege for the table or tables underlying the view. For more information about SQL privileges, see the security chapter in the Data Definition Guide.

Creating a view for SELECT

Many views combine data from multiple tables or other views. A view based on multiple tables or other views can be read, but not updated. For example, the following statement creates a read-only view, PHONE_LIST, because it joins two tables, EMPLOYEE, and DEPARTMENT:

```
EXEC SQL
CREATE VIEW PHONE_LIST AS
  SELECT EMP_NO, FIRST_NAME, LAST_NAME, LOCATION, PHONE_NO
  FROM EMPLOYEE, DEPARTMENT
  WHERE EMPLOYEE.DEPT_NO = DEPARTMENT.DEPT_NO;
EXEC SQL
COMMIT;
```

IMPORTANT Only a view’s creator initially has access to it. To assign read access to others, use GRANT. For more information about GRANT, see the security chapter of the Data Definition Guide.

Creating a view for update

An updatable view is one that enables privileged users to insert, update, and delete information in the view’s base table. To be updatable, a view must meet the following conditions:

- It derives its columns from a single table or updatable view.
- It does not define a self-join of the base table.
- It does not reference columns derived from arithmetic expressions.
- The view’s SELECT statement does not contain:
· A WHERE clause that uses the DISTINCT predicate
· A HAVING clause
· Functions
· Nested queries
· Stored procedures

In the following view, HIGH_CITIES is an updatable view. It selects all cities in the CITIES table with altitudes greater than or equal to a half mile.

EXEC SQL
    CREATE VIEW HIGH_CITIES AS
    SELECT CITY, COUNTRY_NAME, ALTITUDE FROM CITIES
    WHERE ALTITUDE >= 2640;
EXEC SQL
    COMMIT;

Users who have INSERT and UPDATE privileges for this view can change rows in or add new rows to the view’s underlying table, CITIES. They can even insert or update rows that cannot be displayed by the HIGH_CITIES view. The following INSERT adds a record for Santa Cruz, California, altitude 23 feet, to the CITIES table:

EXEC SQL
    INSERT INTO HIGH_CITIES (CITY, COUNTRY_NAME, ALTITUDE)
    VALUES ('Santa Cruz', 'United States', '23');

To restrict inserts and updates through a view to only those rows that can be selected by the view, use the WITH CHECK OPTION in the view definition. For example, the following statement defines the view, HIGH_CITIES, to use the WITH CHECK OPTION. Users with INSERT and UPDATE privileges will be able to enter rows only for cities with altitudes greater than or equal to a half mile.

EXEC SQL
    CREATE VIEW HIGH_CITIES AS
    SELECT CITY, COUNTRY_NAME, ALTITUDE FROM CITIES
    WHERE ALTITUDE > 2640 WITH CHECK OPTION;

---

**Creating an index**

SQL provides CREATE INDEX for establishing user-defined database indexes. An index, based on one or more columns in a table, is used to speed data retrieval for queries that access those columns. The syntax for CREATE INDEX is:
EXEC SQL
  CREATE [UNIQUE] [ASC[ENDING] | DESC[ENDING]] INDEX <index> ON
  table (col [, col ...]);

For example, the following statement defines an index, NAMEX, for the LAST_NAME and
FIRST_NAME columns in the EMPLOYEE table:
EXEC SQL
  CREATE INDEX NAMEX ON EMPLOYEE (LAST_NAME, FIRST_NAME);

Note InterBase automatically generates system-level indexes when tables are defined
using UNIQUE and PRIMARY KEY constraints. For more information about constraints, see
the Data Definition Guide.

See the Language Reference for more information about CREATE INDEX syntax.

» Preventing duplicate index entries
To define an index that eliminates duplicate entries, include the UNIQUE keyword in
CREATE INDEX. The following statement creates a unique index, PRODTYPEX, on the
PROJECT table:
EXEC SQL
  CREATE UNIQUE INDEX PRODTYPEX ON PROJECT (PRODUCT, PROJ_NAME);

IMPORTANT After a unique index is defined, users cannot insert or update values in indexed columns
if those values already exist there. For unique indexes defined on multiple columns, like
PRODTYPEX in the previous example, the same value can be entered within individual
columns, but the combination of values entered in all columns defined for the index
must be unique.

» Specifying index sort order
By default, SQL stores an index in ascending order. To make a descending sort on a
column or group of columns more efficient, use the DESCENDING keyword to define the
index. For example, the following statement creates an index, CHANGEX, based on the
CHANGE_DATE column in the SALARY_HISTORY table:
EXEC SQL
  CREATE DESCENDING INDEX CHANGEX ON SALARY_HISTORY (CHANGE_DATE);

Note To retrieve indexed data in descending order, use ORDER BY in the SELECT statement
to specify retrieval order.
Creating generators

A generator is a monotonically increasing or decreasing numeric value that is inserted in a field either directly by an SQL statement in an application or through a trigger. Generators are often used to produce unique values to insert into a column used as a primary key.

To create a generator for use in an application, use the following CREATE GENERATOR syntax:

```sql
EXEC SQL
    CREATE GENERATOR name;
```

The following statement creates a generator, EMP_NO_GEN, to specify a unique employee number:

```sql
EXEC SQL
    CREATE GENERATOR EMP_NO_GEN;
EXEC SQL
    COMMIT;
```

Once a generator is created, the starting value for a generated number can be specified with SET GENERATOR. To insert a generated number in a field, use the InterBase library GEN_ID() function in an assignment statement. For more information about GEN_ID(), CREATE GENERATOR, and SET GENERATOR, see the Data Definition Guide.

Dropping metadata

SQL supports several statements for deleting existing metadata:

- DROP TABLE, to delete a table from a database
- DROP VIEW, to delete a view definition from a database
- DROP INDEX, to delete a database index
- ALTER TABLE, to delete columns from a table

For more information about deleting columns with ALTER TABLE, see “Altering a table” on page 101.
**Dropping an index**

To delete an index, use DROP INDEX. An index can only be dropped by its creator, the SYSDBA, or a user with root privileges. If an index is in use when the drop is attempted, the drop is postponed until the index is no longer in use. The syntax of DROP INDEX is:

```
EXEC SQL
  DROP INDEX name;
```

`name` is the name of the index to delete. For example, the following statement drops the index, NEEDX:

```
EXEC SQL
  DROP INDEX NEEDX;
EXEC SQL
  COMMIT;
```

Deletion fails if the index is on a UNIQUE, PRIMARY KEY, or FOREIGN KEY integrity constraint. To drop an index on a UNIQUE, PRIMARY KEY, or FOREIGN KEY integrity constraint, first drop the constraints, the constrained columns, or the table.

For more information about DROP INDEX and dropping integrity constraints, see the *Data Definition Guide*.

**Dropping a view**

To delete a view, use DROP VIEW. A view can only be dropped by its owner, the SYSDBA, or a user with root privileges. If a view is in use when a drop is attempted, the drop is postponed until the view is no longer in use. The syntax of DROP VIEW is:

```
EXEC SQL
  DROP VIEW name;
```

The following statement drops the EMPLOYEE_SALARY view:

```
EXEC SQL
  DROP VIEW EMPLOYEE_SALARY;
EXEC SQL
  COMMIT;
```

Deleting a view fails if a view is used in another view, a trigger, or a computed column. To delete a view that meets any of these conditions:

1. Delete the other view, trigger, or computed column.
2. Delete the view.
Dropping a table

Use DROP TABLE to remove a table from a database. A table can only be dropped by its owner, the SYSDBA, or a user with root privileges. If a table is in use when a drop is attempted, the drop is postponed until the table is no longer in use. The syntax of DROP TABLE is:

```sql
EXEC SQL
   DROP TABLE name;
```

`name` is the name of the table to drop. For example, the following statement drops the EMPLOYEE table:

```sql
EXEC SQL
   DROP TABLE EMPLOYEE;
EXEC SQL
   COMMIT;
```

Deleting a table fails if a table is used in a view, a trigger, or a computed column. A table cannot be deleted if a UNIQUE or PRIMARY KEY integrity constraint is defined for it, and the constraint is also referenced by a FOREIGN KEY in another table. To drop the table, first drop the FOREIGN KEY constraints in the other table, then drop the table.

**Note** Columns within a table can be dropped without dropping the rest of the table. For more information, see “Dropping an existing column” on page 102.

For more information about DROP TABLE, see the *Data Definition Guide*.

---

### Altering metadata

Most changes to data definitions are made at the table level, and involve adding new columns to a table, or dropping obsolete columns from it. SQL provides ALTER TABLE to add new columns to a table and to drop existing columns. A single ALTER TABLE can carry out a single operation, or both operations.

Making changes to views and indexes always requires two separate statements:

1. Drop the existing definition.
2. Create a new definition.

If current metadata cannot be dropped, replacement definitions cannot be added.

Dropping metadata can fail for the following reasons:
ALTERING METADATA

- The person attempting to drop metadata is not the metadata's creator.
- SQL integrity constraints are defined for the metadata and referenced in other metadata.
- The metadata is used in another view, trigger, or computed column.

For more information about dropping metadata, see "Dropping metadata" on page 98.

Altering a table

ALTER TABLE enables the following changes to an existing table:
- Adding new column definitions
- Adding new table constraints
- Dropping existing column definitions
- Dropping existing table constraints
- Changing column definitions by dropping existing definitions, and adding new ones
- Changing existing table constraints by dropping existing definitions, and adding new ones
- Modifying column names and datatypes

The simple syntax of ALTER TABLE is as follows:

```
EXEC SQL
ALTER TABLE name  {ADD colname < datatype > [NOT NULL]
| ALTER [COLUMN] simple_column_name alter_rel_field
| DROP colname | ADD CONSTRAINT constraintname tableconstraint
| DROP CONSTRAINT constraintname};
```

Note For information about adding, dropping, and modifying constraints at the table level, see the Data Definition Guide.

For the complete syntax of ALTER TABLE, see the Language Reference.

- Adding a new column to a table

To add another column to an existing table, use ALTER TABLE. A table can only be modified by its creator. The syntax for adding a column with ALTER TABLE is:

```
EXEC SQL
ALTER TABLE name ADD colname <datatype> colconstraint
[, ADD colname datatype colconstraint ...];
```

For example, the following statement adds a column, EMP_NO, to the EMPLOYEE table:
This example makes use of a domain, EMPNO, to define a column. For more information about domains, see the Data Definition Guide.

Multiple columns can be added to a table at the same time. Separate column definitions with commas. For example, the following statement adds two columns, EMP_NO, and FULL_NAME, to the EMPLOYEE table. FULL_NAME is a computed column, a column that derives its values from calculations based on other columns:

EXEC SQL
  ALTER TABLE EMPLOYEE
  ADD EMP_NO EMPNO NOT NULL,
  ADD FULL_NAME COMPUTED BY (LAST_NAME || ', ' || FIRST_NAME);
EXEC SQL
  COMMIT;

This example creates a column using a value computed from two other columns already defined for the EMPLOYEE table. For more information about creating computed columns, see the Data Definition Guide.

New columns added to a table can be defined with integrity constraints. For more information about adding columns with integrity constraints to a table, see the Data Definition Guide.

Dropping an existing column

To delete a column definition and its data from a table, use ALTER TABLE. A column can only be dropped by the owner of the table, the SYSDBA, or a user with root privileges. If a table is in use when a column is dropped, the drop is postponed until the table is no longer in use. The syntax for dropping a column with ALTER TABLE is:

EXEC SQL
  ALTER TABLE name DROP colname [, colname ...];

For example, the following statement drops the EMP_NO column from the EMPLOYEE table:

EXEC SQL
  ALTER TABLE EMPLOYEE DROP EMP_NO;
EXEC SQL
  COMMIT;

Multiple columns can be dropped with a single ALTER TABLE. The following statement drops the EMP_NO and FULL_NAME columns from the EMPLOYEE table:
ALTERING METADATA

EXEC SQL
  ALTER TABLE EMPLOYEE
    DROP EMP_NO,
    DROP FULL_NAME;
EXEC SQL
  COMMIT;

Deleting a column fails if the column is part of a UNIQUE, PRIMARY KEY, or FOREIGN KEY constraint. To drop the column, first drop the constraint, then the column.

Deleting a column also fails if the column is used by a CHECK constraint for another column. To drop the column, first drop the CHECK constraint, then drop the column.

For more information about integrity constraints, see the Data Definition Guide.

Modifying a column

An existing column definition can be modified using ALTER TABLE, but if data already stored in that column is not preserved before making changes, it will be lost.

Preserving data entered in a column and modifying the definition for a column, is a five-step process:

1. Adding a new, temporary column to the table that mirrors the current metadata of the column to be changed.
2. Copying the data from the column to be changed to the newly created temporary column.
3. Modifying the column.
4. Copying data from the temporary column to the redefined column.
5. Dropping the temporary column.

For example, suppose the EMPLOYEE table contains a column, OFFICE_NO, defined to hold a datatype of CHAR(3), and suppose that the size of the column needs to be increased by one. The following numbered sequence describes each step and provides sample code:

1. First, create a temporary column to hold the data in OFFICE_NO during the modification process:

   EXEC SQL
   ALTER TABLE EMPLOYEE ADD TEMP_NO CHAR(3);
   EXEC SQL
   COMMIT;

2. Move existing data from OFFICE_NO to TEMP_NO to preserve it:

   EXEC SQL
   UPDATE EMPLOYEE
3. Modify the new column definition for OFFICE_NO, specifying the datatype and new size:

```sql
EXEC SQL
  ALTER TABLE EMPLOYEE ALTER OFFICE_NO TYPE CHAR(4);
EXEC SQL
COMMIT;
```

4. Move the data from TEMP_NO to OFFICE_NO:

```sql
EXEC SQL
  UPDATE EMPLOYEE
  SET OFFICE_NO = TEMP_NO;
```

5. Finally, drop the TEMP_NO column:

```sql
EXEC SQL
  ALTER TABLE DROP TEMP_NO;
EXEC SQL
COMMIT;
```

- For more information about dropping column definitions, see “Dropping an existing column” on page 102. For more information about adding column definitions, see Modifying columns in a table.

The ALTER TABLE ALTER command allows you to change the column position and name as well.

For example, the following statement moves a column, EMP_NO, from the third position to the second position in the EMPLOYEE table:

```sql
ALTER TABLE EMPLOYEE ALTER EMP_NO POSITION 2;
```

You could also change the name of the EMP_NO column to EMP_NUM as in the following example:

```sql
ALTER TABLE EMPLOYEE ALTER EMP_NO TO EMP_NUM;
```

- Any changes to the field definitions may require the indexes to be rebuilt.

For the complete syntax of ALTER TABLE, see the Language Reference.
### Altering a view

To change the information provided by a view, follow these steps:

1. Drop the current view definition.
2. Create a new view definition and give it the same name as the dropped view.

For example, the following view is defined to select employee salary information:

```sql
EXEC SQL
CREATE VIEW EMPLOYEE_SALARY AS
    SELECT EMP_NO, LAST_NAME, CURRENCY, SALARY
    FROM EMPLOYEE, COUNTRY
    WHERE EMPLOYEE.COUNTRY_CODE = COUNTRY.CODE;
```

Suppose the full name of each employee should be displayed instead of the last name. First, drop the current view definition:

```sql
EXEC SQL
DROP EMPLOYEE_SALARY;
EXEC SQL
COMMIT;
```

Then create a new view definition that displays each employee’s full name:

```sql
EXEC SQL
CREATE VIEW EMPLOYEE_SALARY AS
    SELECT EMP_NO, FULL_NAME, CURRENCY, SALARY
    FROM EMPLOYEE, COUNTRY
    WHERE EMPLOYEE.COUNTRY_CODE = COUNTRY.CODE;
EXEC SQL
COMMIT;
```

### Altering an index

To change the definition of an index, follow these steps:

1. Use `ALTER INDEX` to make the current index inactive.
2. Drop the current index.
3. Create a new index and give it the same name as the dropped index.

An index is usually modified to change the combination of columns that are indexed, to prevent or allow insertion of duplicate entries, or to specify index sort order. For example, given the following definition of the `NAMEX` index:
EXEC SQL
  CREATE INDEX NAMEX ON EMPLOYEE (LAST_NAME, FIRST_NAME);

Suppose there is an additional need to prevent duplicate entries with the UNIQUE keyword. First, make the current index inactive, then drop it:

EXEC SQL
  ALTER INDEX NAMEX INACTIVE;
EXEC SQL
  DROP INDEX NAMEX;
EXEC SQL
  COMMIT;

Then create a new index, NAMEX, based on the previous definition, that also includes the UNIQUE keyword:

EXEC SQL
  CREATE UNIQUE INDEX NAMEX ON EMPLOYEE (LAST_NAME, FIRST_NAME);
EXEC SQL
  COMMIT

ALTER INDEX can be used directly to change an index’s sort order, or to add the ability to handle unique or duplicate entries. For example, the following statement changes the NAMEX index to permit duplicate entries:

EXEC SQL
  ALTER INDEX NAMEX DUPLICATE;

**IMPORTANT**  Be careful when altering an index directly. For example, changing an index from supporting duplicate entries to one that requires unique entries without disabling the index and recreating it can reduce index performance.

For more information about dropping an index, see “Dropping an index” on page 99. For more information about creating an index, see “Creating an index” on page 96.
The majority of SQL statements in an embedded program are devoted to reading or modifying existing data, or adding new data to a database. This chapter describes the types of data recognized by InterBase, and how to retrieve, modify, add, or delete data in a database using SQL expressions and the following statements.

- **SELECT** statements query a database, that is, read or retrieve existing data from a database. Variations of the **SELECT** statement make it possible to retrieve:
  - A single row, or part of a row, from a table. This operation is referred to as a *singleton select*.
  - Multiple rows, or parts of rows, from a table using a **SELECT** within a **DECLARE CURSOR** statement.
  - Related rows, or parts of rows, from two or more tables into a *virtual table*, or *results table*. This operation is referred to as a *join*.
  - All rows, or parts of rows, from two or more tables into a virtual table. This operation is referred to as a *union*.

- **INSERT** statements write new rows of data to a table.
- **UPDATE** statements modify existing rows of data in a table.
- **DELETE** statements remove existing rows of data from a table.
To learn how to use the SELECT statement to retrieve data, see “Understanding data retrieval with SELECT” on page 126. For information about retrieving a single row with SELECT, see “Selecting a single row” on page 143. For information about retrieving multiple rows, see “Selecting multiple rows” on page 144.

For information about using INSERT to write new data to a table, see “Inserting data” on page 164. To modify data with UPDATE, see “Updating data” on page 170. To remove data from a table with DELETE, see “Deleting data” on page 176.

**Supported datatypes**

To query or write to a table, it is necessary to know the structure of the table, what columns it contains, and what datatypes are defined for those columns. InterBase supports ten fundamental datatypes, described in the following table:

<table>
<thead>
<tr>
<th>Name</th>
<th>Size</th>
<th>Range/Precision</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BLOB</td>
<td>Variable</td>
<td>• None</td>
<td>• Dynamically sizable datatype for storing large data such as graphics, text, and digitized voice</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Blob segment size is limited to 64K</td>
<td>• Basic structural unit is the segment</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Blob subtype describes Blob contents</td>
</tr>
<tr>
<td>CHAR(n)</td>
<td>n characters</td>
<td>• 1 to 32,767 bytes</td>
<td>• Fixed length CHAR or text string type</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Character set character size determines the maximum number of characters that can fit in 32K</td>
<td>• Alternate keyword: CHARACTER</td>
</tr>
<tr>
<td>DATE</td>
<td>64 bits</td>
<td>1 Jan 100 a.d. to 29 Feb 32768 a.d.</td>
<td>ISC_DATE</td>
</tr>
<tr>
<td>DECIMAL</td>
<td>Variable (16, 32, or 64 bits)</td>
<td>• precision = 1 to 18; specifies at least precision digits of precision to store</td>
<td>• Number with a decimal point scale digits from the right</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• scale = 1 to 18; specifies number of decimal places for storage</td>
<td>• Example: DECIMAL(10, 3) holds numbers accurately in the following format: ppppppp.sss</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Must be less than or equal to precision</td>
<td></td>
</tr>
<tr>
<td>DOUBLE PRECISION</td>
<td>64 bits</td>
<td>2.225 x 10^{-308} to 1.797 x 10^{308}</td>
<td>IEEE double precision: 15 digits</td>
</tr>
<tr>
<td>FLOAT</td>
<td>32 bits</td>
<td>1.175 x 10^{-38} to 3.402 x 10^{38}</td>
<td>IEEE single precision: 7 digits</td>
</tr>
<tr>
<td>INTEGER</td>
<td>32 bits</td>
<td>-2,147,483,648 to 2,147,483,647</td>
<td>Signed long (longword)</td>
</tr>
</tbody>
</table>

*TABLE 6.1 Datatypes supported by InterBase*
The BLOB datatype can store large data objects of indeterminate and variable size, such as bitmapped graphics images, vector drawings, sound files, chapter or book-length documents, or any other kind of multimedia information. Because a Blob can hold different kinds of information, it requires special processing for reading and writing. For more information about Blob handling, see Chapter 8, “Working with Blob Data.”

The DATE, TIME, and TIMESTAMP datatypes may require conversion to and from InterBase when entered or manipulated in a host-language program. For more information about retrieving and writing dates, see Chapter 7, “Working with Dates.”

InterBase also supports arrays of most datatypes. An array is a matrix of individual items, all of any single InterBase datatype, except Blob, that can be handled either as a single entity, or manipulated item by item. To learn more about the flexible data access provided by arrays, see Chapter 9, “Using Arrays.”

For a complete discussion of InterBase datatypes, see the Data Definition Guide.
Understanding SQL expressions

All SQL data manipulation statements support *SQL expressions*, SQL syntax for comparing and evaluating columns, constants, and host-language variables to produce a single value.

In the SELECT statement, for example, the WHERE clause is used to specify a *search condition* that determines if a row qualifies for retrieval. That search condition is an SQL expression. DELETE and UPDATE also support search condition expressions. Typically, when an expression is used as a search condition, the expression evaluates to a Boolean value that is True, False, or Unknown.

SQL expressions can also appear in the INSERT statement VALUE clause and the UPDATE statement SET clause to specify or calculate values to insert into a column. When inserting or updating a numeric value via an expression, the expression is usually arithmetic, such as multiplying one number by another to produce a new number which is then inserted or updated in a column. When inserting or updating a string value, the expression may *concatenate*, or combine, two strings to produce a single string for insertion or updating.

The following table describes the elements that can be used in expressions:

<table>
<thead>
<tr>
<th>Element</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column names</td>
<td>Columns from specified tables, against which to search or compare values, or from which to calculate values.</td>
</tr>
<tr>
<td>Host-language variables</td>
<td>Program variables containing changeable values. Host-language variables must be preceded by a colon (:).</td>
</tr>
<tr>
<td>Constants</td>
<td>Hard-coded numbers or quoted strings, like 507 or “Tokyo”.</td>
</tr>
<tr>
<td>Concatenation operator</td>
<td></td>
</tr>
<tr>
<td>Arithmetic operators</td>
<td>+, -, *, and /, used to calculate and evaluate values.</td>
</tr>
<tr>
<td>Logical operators</td>
<td>Keywords, NOT, AND, and OR, used within simple search conditions, or to combine simple search conditions to make complex searches. A logical operation evaluates to true or false. Usually used only in search conditions.</td>
</tr>
</tbody>
</table>

*TABLE 6.2 Elements of SQL expressions*
Complex expressions can be constructed by combining simple expressions in different ways. For example, the following WHERE clause uses a column name, three constants, three comparison operators, and a set of grouping parentheses to retrieve only those rows for employees with salaries between $60,000 and $120,000:

```
WHERE DEPARTMENT = 'Publications' AND
(SALARY > 60000 AND SALARY < 120000)
```
As another example, search conditions in WHERE clauses often contain nested SELECT statements, or subqueries. In the following query, the WHERE clause contains a subquery that uses the aggregate function, AVG(), to retrieve a list of all departments with bigger than average salaries:

```
EXEC SQL
    DECLARE WELL_PAID CURSOR FOR
    SELECT DEPT_NO
      INTO :wellpaid
      FROM DEPARTMENT
      WHERE SALARY > (SELECT AVG(SALARY) FROM DEPARTMENT);
```

For more information about using subqueries to specify search conditions, see “Using subqueries” on page 161. For more information about aggregate functions, see “Retrieving aggregate column information” on page 129.

---

### Using the string operator in expressions

The string operator, `||`, also referred to as a concatenation operator, enables a single character string to be built from two or more character strings. Character strings can be constants or values retrieved from a column. For example,

```c
char strbuf[80];
...
EXEC SQL
    SELECT LAST_NAME || ' is the manager of publications.'
      INTO :strbuf
      FROM DEPARTMENT, EMPLOYEE
      WHERE DEPT_NO = 5900 AND MNGR_NO = EMP_NO;
```

The string operator can also be used in INSERT or UPDATE statements:

```
EXEC SQL
    INSERT INTO DEPARTMENT (MANAGER_NAME)
    VALUES (:fname || :lname);
```
Using arithmetic operators in expressions

To calculate numeric values in expressions, InterBase recognizes four arithmetic operators listed in the following table:

<table>
<thead>
<tr>
<th>Operator</th>
<th>Purpose</th>
<th>Precedence</th>
<th>Operator</th>
<th>Purpose</th>
<th>Precedence</th>
</tr>
</thead>
<tbody>
<tr>
<td>*</td>
<td>Multiplication</td>
<td>1</td>
<td>+</td>
<td>Addition</td>
<td>3</td>
</tr>
<tr>
<td>/</td>
<td>Division</td>
<td>2</td>
<td>–</td>
<td>Subtraction</td>
<td>4</td>
</tr>
</tbody>
</table>

Arithmetic operators are evaluated from left to right, except when ambiguities arise. In these cases, InterBase evaluates operations according to the precedence specified in the table (for example, multiplications are performed before divisions, and divisions are performed before subtractions).

Arithmetic operations are always calculated before comparison and logical operations. To change or force the order of evaluation, group operations in parentheses. InterBase calculates operations within parentheses first. If parentheses are nested, the equation in the innermost set is the first evaluated, and the outermost set is evaluated last. For more information about precedence and using parentheses for grouping, see “Determining precedence of operators” on page 122.

The following example illustrates a WHERE clause search condition that uses an arithmetic operator to combine the values from two columns, then uses a comparison operator to determine if that value is greater than 10:

```sql
DECLARE RAINCITIES CURSOR FOR
  SELECT CITYNAME, COUNTRYNAME
  INTO :cityname, :countryname
  FROM CITIES
  WHERE JANUARY_RAIN + FEBRUARY_RAIN > 10;
```

Using logical operators in expressions

Logical operators calculate a Boolean value, True, False, or Unknown, based on comparing previously calculated simple search conditions immediately to the left and right of the operator. InterBase recognizes three logical operators, NOT, AND, and OR.

NOT reverses the search condition in which it appears, while AND and OR are used to combine simple search conditions. For example, the following query returns any employee whose last name is not “Smith”:  

```sql
DECLARE RAINCITIES CURSOR FOR
  SELECT CITYNAME, COUNTRYNAME
  INTO :cityname, :countryname
  FROM CITIES
  WHERE NOT LASTNAME = 'Smith';
```
DECLARE NOSMITH CURSOR FOR
  SELECT LAST_NAME
  INTO :lname
  FROM EMPLOYEE
  WHERE NOT LNAME = 'Smith';

When AND appears between search conditions, both search conditions must be true if a row is to be retrieved. The following query returns any employee whose last name is neither “Smith” nor “Jones”:

DECLARE NO_SMITH_OR_JONES CURSOR FOR
  SELECT LAST_NAME
  INTO :lname
  FROM EMPLOYEE
  WHERE NOT LNAME = 'Smith' AND NOT LNAME = 'Jones';

OR stipulates that one search condition or the other must be true. For example, the following query returns any employee named “Smith” or “Jones”:

DECLARE ALL_SMITH_JONES CURSOR FOR
  SELECT LAST_NAME, FIRST_NAME
  INTO :lname, :fname
  FROM EMPLOYEE
  WHERE LNAME = 'Smith' OR LNAME = 'Jones';

The order in which combined search conditions are evaluated is dictated by the precedence of the operators that connect them. A NOT condition is evaluated before AND, and AND is evaluated before OR. Parentheses can be used to change the order of evaluation. For more information about precedence and using parentheses for grouping, see “Determining precedence of operators” on page 122.

**Using comparison operators in expressions**

Comparison operators evaluate to a Boolean value: True, False, or Unknown, based on a test for a specific relationship between a value to the left of the operator, and a value or range of values to the right of the operator. Values compared must evaluate to the same datatype, unless the CAST() function is used to translate one datatype to a different one for comparison. Values can be columns, constants, or calculated values.

The following table lists operators that can be used in statements, describes how they are used, and provides samples of their use:

**Note** Comparisons evaluate to Unknown if a NULL value is encountered.
For more information about CAST(), see “Using CAST( ) for datatype conversions” on page 125.

InterBase also supports comparison operators that compare a value on the left of the operator to the results of a subquery to the right of the operator. The following table lists these operators, and describes how they are used:

<table>
<thead>
<tr>
<th>Operator</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALL</td>
<td>Determines if a value is equal to all values returned by a subquery</td>
</tr>
<tr>
<td>ANY and SOME</td>
<td>Determines if a value is equal to any values returned by a subquery</td>
</tr>
<tr>
<td>EXISTS</td>
<td>Determines if a value exists in at least one value returned by a subquery</td>
</tr>
<tr>
<td>SINGULAR</td>
<td>Determines if a value exists in exactly one value returned by a subquery</td>
</tr>
</tbody>
</table>

**TABLE 6.4** InterBase comparison operators requiring subqueries

For more information about using subqueries, see “Using subqueries” on page 161.

*Using BETWEEN*

BETWEEN tests whether a value falls within a range of values. The complete syntax for the BETWEEN operator is:

```
<value> [NOT] BETWEEN <value> AND <value>
```

For example, the following cursor declaration retrieves LAST_NAME and FIRST_NAME columns for employees with salaries between $100,000 and $250,000, inclusive:

```
EXEC SQL
    DECLARE LARGE_SALARIES CURSOR FOR
    SELECT LAST_NAME, FIRST_NAME
    FROM EMPLOYEE
    WHERE SALARY BETWEEN 100000 AND 250000;
```

Use NOT BETWEEN to test whether a value falls outside a range of values. For example, the following cursor declaration retrieves the names of employees with salaries less than $30,000 and greater than $150,000:

```
EXEC SQL
    DECLARE EXTREME_SALARIES CURSOR FOR
    SELECT LAST_NAME, FIRST_NAME
    FROM EMPLOYEE
    WHERE SALARY NOT BETWEEN 30000 AND 150000;
```
CHAPTER 6 WORKING WITH DATA

Using CONTAINING

CONTAINING tests to see if an ASCII string value contains a quoted ASCII string supplied by the program. String comparisons are case-insensitive; “String”, “STRING”, and “string” are equivalent values for CONTAINING. Note that for Dialect 3 databases and clients, the strings must be enclosed in single quotation marks. The complete syntax for CONTAINING is:

<value> [NOT] CONTAINING ‘<string>’

For example, the following cursor declaration retrieves the names of all employees whose last names contain the three-letter combination, “las” (and “LAS” or “Las”):

EXEC SQL
    DECLARE LAS_EMP CURSOR FOR
        SELECT LAST_NAME, FIRST_NAME
        FROM EMPLOYEE
        WHERE LAST_NAME CONTAINING ’las’;

Use NOT CONTAINING to test for strings that exclude a specified value. For example, the following cursor declaration retrieves the names of all employees whose last names do not contain “las” (also “LAS” or “Las”):

EXEC SQL
    DECLARE NOT_LAS_EMP CURSOR FOR
        SELECT LAST_NAME, FIRST_NAME
        FROM EMPLOYEE
        WHERE LAST_NAME NOT CONTAINING ’las’;

Tip CONTAINING can be used to search a Blob segment by segment for an occurrence of a quoted string.

Using IN

IN tests that a known value equals at least one value in a list of values. A list is a set of values separated by commas and enclosed by parentheses. The values in the list must be parenthesized and separated by commas. If the value being compared to a list of values is NULL, IN returns Unknown.

The syntax for IN is:

<value> [NOT] IN (<value> [, <value> ...])
For example, the following cursor declaration retrieves the names of all employees in the accounting, payroll, and human resources departments:

EXEC SQL
DECLARE ACCT_PAY_HR CURSOR FOR
SELECT DEPARTMENT, LAST_NAME, FIRST_NAME, EMP_NO
FROM EMPLOYEE EMP, DEPTARTMENT DEP
WHERE EMP.DEPT_NO = DEP.DEPT_NO AND
    DEPARTMENT IN ('Accounting', 'Payroll', 'Human Resources')
GROUP BY DEPARTMENT;

Use NOT IN to test that a value does not occur in a set of specified values. For example, the following cursor declaration retrieves the names of all employees not in the accounting, payroll, and human resources departments:

EXEC SQL
DECLARE NOT_ACCT_PAY_HR CURSOR FOR
SELECT DEPARTMENT, LAST_NAME, FIRST_NAME, EMP_NO
FROM EMPLOYEE EMP, DEPTARTMENT DEP
WHERE EMP.DEPT_NO = DEP.DEPT_NO AND
    DEPARTMENT NOT IN ('Accounting', 'Payroll', 'Human Resources')
GROUP BY DEPARTMENT;

IN can also be used to compare a value against the results of a subquery. For example, the following cursor declaration retrieves all cities in Europe:

EXEC SQL
DECLARE NON_JFG_CITIES CURSOR FOR
SELECT C.COUNTRY, C.CITY, C.POPULATION
FROM CITIES C
WHERE C.COUNTRY NOT IN (SELECT O.COUNTRY FROM COUNTRIES O
    WHERE O.CONTINENT <> 'Europe')
GROUP BY C.COUNTRY;

For more information about subqueries, see “Using subqueries” on page 161.

- **Using LIKE**

LIKE is a case-sensitive operator that tests a string value against a string containing wildcards, symbols that substitute for a single, variable character, or a string of variable characters. LIKE recognizes two wildcard symbols:

- % (percent) substitutes for a string of zero or more characters.
- _ (underscore) substitutes for a single character.
The syntax for LIKE is:

\[ <value> \ [\text{NOT}] \ \text{LIKE} \ <value> \ [\text{ESCAPE} \ 'symbol'] \]

For example, this cursor retrieves information about any employee whose last names contain the three letter combination “ton” (but not “Ton”):

EXEC SQL
   DECLARE TON_EMP CURSOR FOR
   SELECT LAST_NAME, FIRST_NAME, EMP_NO
   FROM EMPLOYEE
   WHERE LAST_NAME LIKE '%ton%';

To test for a string that contains a percent or underscore character:

1. Precede the \% or _ with another symbol (for example, @), in the quoted comparison string.
2. Use the ESCAPE clause to identify the symbol (@, in this case) preceding \% or _ as a literal symbol. A literal symbol tells InterBase that the next character should be included as is in the search string.

For example, this cursor retrieves all table names in RDB$RELATIONS that have underscores in their names:

EXEC SQL
   DECLARE UNDER_TABLE CURSOR FOR
   SELECT RDB$RELATION_NAME
   FROM RDB$RELATIONS
   WHERE RDB$RELATION_NAME LIKE '%@_%' ESCAPE '@';

Use NOT LIKE to retrieve rows that do not contain strings matching those described. For example, the following cursor retrieves all table names in RDB$RELATIONS that do not have underscores in their names:

EXEC SQL
   DECLARE NOT_UNDER_TABLE CURSOR FOR
   SELECT RDB$RELATION_NAME
   FROM RDB$RELATIONS
   WHERE RDB$RELATION_NAME NOT LIKE '%@_%' ESCAPE '@';

\[ \text{Using IS NULL} \]

IS NULL tests for the absence of a value in a column. The complete syntax of the IS NULL clause is:

\[ <value> \ \text{IS} \ [\text{NOT}] \ \text{NULL} \]
For example, the following cursor retrieves the names of employees who do not have phone extensions:

```
EXEC SQL
  DECLARE MISSING_PHONE CURSOR FOR
  SELECT LAST_NAME, FIRST_NAME
  FROM EMPLOYEE
  WHERE PHONE_EXT IS NULL;
```

Use `IS NOT NULL` to test that a column contains a value. For example, the following cursor retrieves the phone numbers of all employees that have phone extensions:

```
EXEC SQL
  DECLARE PHONE_LIST CURSOR FOR
  SELECT LAST_NAME, FIRST_NAME, PHONE_EXT
  FROM EMPLOYEE
  WHERE PHONE_EXT IS NOT NULL
  ORDER BY LAST_NAME, FIRST_NAME;
```

### Using `STARTING WITH`

`STARTING WITH` is a case-sensitive operator that tests a string value to see if it begins with a stipulated string of characters. To support international character set conversions, `STARTING WITH` follows byte-matching rules for the specified collation order. The complete syntax for `STARTING WITH` is:

```
<value> [NOT] STARTING WITH <value>
```

For example, the following cursor retrieves employee last names that start with “To”:

```
EXEC SQL
  DECLARE TO_EMP CURSOR FOR
  SELECT LAST_NAME, FIRST_NAME
  FROM EMPLOYEE
  WHERE LAST_NAME STARTING WITH 'To';
```

Use `NOT STARTING WITH` to retrieve information for columns that do not begin with the stipulated string. For example, the following cursor retrieves all employees except those whose last names start with “To”:

```
EXEC SQL
  DECLARE NOT_TO_EMP CURSOR FOR
  SELECT LAST_NAME, FIRST_NAME
  FROM EMPLOYEE
  WHERE LAST_NAME NOT STARTING WITH 'To';
```

For more information about collation order and byte-matching rules, see the *Data Definition Guide*. 
Using ALL

ALL tests that a value is true when compared to every value in a list returned by a subquery. The complete syntax for ALL is:

```
<value> <comparison_operator> ALL (<subquery>)
```

For example, the following cursor retrieves information about employees whose salaries are larger than that of the vice president of channel marketing:

```sql
EXEC SQL
    DECLARE MORE_THAN_VP CURSOR FOR
    SELECT LAST_NAME, FIRST_NAME, SALARY
    FROM EMPLOYEE
    WHERE SALARY > ALL (SELECT SALARY FROM EMPLOYEE
                          WHERE DEPT_NO = 7734);
```

ALL returns Unknown if the subquery returns a NULL value. It can also return Unknown if the value to be compared is NULL and the subquery returns any non-NULL data. If the value is NULL and the subquery returns an empty set, ALL evaluates to True.

For more information about subqueries, see “Using subqueries” on page 161.

Using ANY and SOME

ANY and SOME test that a value is true if it matches any value in a list returned by a subquery. The complete syntax for ANY is:

```
<value> <comparison_operator> ANY | SOME (<subquery>)
```

For example, the following cursor retrieves information about salaries that are larger than at least one salary in the channel marketing department:

```sql
EXEC SQL
    DECLARE MORE_CHANNEL CURSOR FOR
    SELECT LAST_NAME, FIRST_NAME, SALARY
    FROM EMPLOYEE
    WHERE SALARY > ANY (SELECT SALARY FROM EMPLOYEE
                         WHERE DEPT_NO = 7734);
```

ANY and SOME return Unknown if the subquery returns a NULL value. They can also return Unknown if the value to be compared is NULL and the subquery returns any non-NULL data. If the value is NULL and the subquery returns an empty set, ANY and SOME evaluate to False.

For more information about subqueries, see “Using subqueries” on page 161.
Using EXISTS

EXISTS tests that for a given value there is at least one qualifying row meeting the search condition specified in a subquery. The SELECT clause in the subquery must use the * (asterisk) to select all columns. The complete syntax for EXISTS is:

\[\text{[NOT]} \ \text{EXISTS (SELECT * FROM <tablelist> WHERE <search_condition>)}\]

The following cursor retrieves all countries with rivers:

```
EXEC SQL
  DECLARE RIVER COUNTRIES CURSOR FOR
    SELECT COUNTRY
    FROM COUNTRIES C
    WHERE EXISTS (SELECT * FROM RIVERS R
                  WHERE R.COUNTRY = C.COUNTRY);
```

Use NOT EXISTS to retrieve rows that do not meet the qualifying condition specified in the subquery. The following cursor retrieves all countries without rivers:

```
EXEC SQL
  DECLARE NON_RIVER COUNTRIES COUNTRIES FOR
    SELECT COUNTRY
    FROM COUNTRIES C
    WHERE NOT EXISTS (SELECT * FROM RIVERS R
                      WHERE R.COUNTRY = C.COUNTRY);
```

EXISTS always returns either True or False, even when handling NULL values.

For more information about subqueries, see “Using subqueries” on page 161.

Using SINGULAR

SINGULAR tests that for a given value there is exactly one qualifying row meeting the search condition specified in a subquery. The SELECT clause in the subquery must use the * (asterisk) to select all columns. The complete syntax for SINGULAR is:

\[\text{[NOT]} \ \text{SINGULAR (SELECT * FROM <tablelist> WHERE <search_condition>)}\]

The following cursor retrieves all countries with a single capital:

```
EXEC SQL
  DECLARE SINGLE_CAPITAL CURSOR FOR
    SELECT COUNTRY
    FROM COUNTRIES C
    WHERE SINGULAR (SELECT * FROM CITIES C
                    WHERE C.CITY = C.COUNTRY);
```
Use NOT SINGULAR to retrieve rows that do not meet the qualifying condition specified in the subquery. For example, the following cursor retrieves all countries with more than one capital:

```sql
EXEC SQL
DECLARE MULTI_CAPITAL CURSOR FOR
SELECT COUNTRY
FROM COUNTRIES COU
WHERE NOT SINGULAR (SELECT * FROM CITIES CIT
WHERE CIT.CITY = COU.CAPITAL);
```

For more information about subqueries, see “Using subqueries” on page 161.

### Determining precedence of operators

The order in which operators and the values they affect are evaluated in a statement is called precedence. There are two levels of precedence for SQL operators:

- Precedence among operators of different types.
- Precedence among operators of the same type.

#### Precedence among operators

**AMONG OPERATORS OF DIFFERENT TYPES**

The following table lists the evaluation order of different InterBase operator types, from first evaluated (highest precedence) to last evaluated (lowest precedence):

<table>
<thead>
<tr>
<th>Operator type</th>
<th>Precedence</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>String</td>
<td>Highest</td>
<td>Strings are always concatenated before all other operations take place.</td>
</tr>
<tr>
<td>Mathematical</td>
<td>?</td>
<td>Math is performed after string concatenation, but before comparison and logical operations.</td>
</tr>
<tr>
<td>Comparison</td>
<td>?</td>
<td>Comparison operations are evaluated after string concatenation and math, but before logical operations.</td>
</tr>
<tr>
<td>Logical</td>
<td>Lowest</td>
<td>Logical operations are evaluated after all other operations.</td>
</tr>
</tbody>
</table>

**TABLE 6.5** Operator precedence by operator type
AMONG OPERATORS OF THE SAME TYPE

When an expression contains several operators of the same type, those operators are evaluated from left to right unless there is a conflict where two operators of the same type affect the same values.

For example, in the mathematical equation, $3 + 2 \times 6$, both the addition and multiplication operators work with the same value, 2. Evaluated from left to right, the equation evaluates to 30: $3 + 2 = 5; 5 \times 6 = 30$. InterBase follows standard mathematical rules for evaluating mathematical expressions, that stipulate multiplication is performed before addition: $2 \times 6 = 12; 3 + 12 = 15$.

The following table lists the evaluation order for all mathematical operators, from highest to lowest:

<table>
<thead>
<tr>
<th>Operator</th>
<th>Precedence</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>*</td>
<td>Highest</td>
<td>Multiplication is performed before all other mathematical operations.</td>
</tr>
<tr>
<td>/</td>
<td>?</td>
<td>Division is performed before addition and subtraction.</td>
</tr>
<tr>
<td>+</td>
<td>?</td>
<td>Addition is performed before subtraction.</td>
</tr>
<tr>
<td>–</td>
<td>Lowest</td>
<td>Subtraction is performed after all other mathematical operations.</td>
</tr>
</tbody>
</table>

**TABLE 6.6** Mathematical operator precedence

InterBase also follows rules for determining the order in which comparison operators are evaluated when conflicts arise during normal left to right evaluation. The next table describes the evaluation order for comparison operators, from highest to lowest:

<table>
<thead>
<tr>
<th>Operator</th>
<th>Precedence</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>=, ===</td>
<td>Highest</td>
<td>Equality operations are evaluated before all other comparison operations.</td>
</tr>
<tr>
<td>&lt;&gt;, !=, ~=, ^=</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>&gt;</td>
<td>?</td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 6.7** Comparison operator precedence
CHAPTER 6 WORKING WITH DATA

Interbase 6

ALL, ANY, BETWEEN, CONTAINING, EXISTS, IN, LIKE, NULL, SINGULAR, SOME, and STARTING WITH are evaluated after all listed comparison operators when they conflict with other comparison operators during normal left to right evaluation. When they conflict with one another they are evaluated strictly from left to right.

When logical operators conflict during normal left to right processing, they, too, are evaluated according to a hierarchy, detailed in the following table:

<table>
<thead>
<tr>
<th>Operator</th>
<th>Precedence</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOT</td>
<td>Highest</td>
<td>NOT operations are evaluated before all other logical operations.</td>
</tr>
<tr>
<td>AND</td>
<td>?</td>
<td>AND operations are evaluated after NOT operations, and before OR operations.</td>
</tr>
<tr>
<td>OR</td>
<td>Lowest</td>
<td>OR operations are evaluated after all other logical operations.</td>
</tr>
</tbody>
</table>

> Changing evaluation order of operators

To change the evaluation order of operations in an expression, use parentheses to group operations that should be evaluated as a unit, or that should derive a single value for use in other operations. For example, without parenthetical grouping, $3 + 2 * 6$ evaluates to 15. To cause the addition to be performed before the multiplication, use parentheses:

$$(3 + 2) * 6 = 30$$

Tip Always use parentheses to group operations in complex expressions, even when default order of evaluation is desired. Explicitly grouped expressions are easier to understand and debug.
Using \texttt{CAST()} for datatype conversions

Normally, only similar datatypes can be compared or evaluated in expressions. The \texttt{CAST()} function can be used in expressions to translate one datatype into another for comparison purposes. The syntax for \texttt{CAST()} is:

\[
\texttt{CAST} \ (<\text{value}> \mid \text{NULL} \ \text{AS} \ \text{datatype})
\]

For example, in the following WHERE clause, \texttt{CAST()} is used to translate a CHAR datatype, \texttt{INTERVIEW\_DATE}, to a DATE datatype to compare against a DATE datatype, \texttt{HIRE\_DATE}:

\[
\text{WHERE } \texttt{HIRE\_DATE} = \texttt{CAST(INTERVIEW\_DATE \ \text{AS} \ DATE)};
\]

\texttt{CAST()} can be used to compare columns with different datatypes in the same table, or across tables. You can convert one datatype to another as shown in the following table:

<table>
<thead>
<tr>
<th>From datatype</th>
<th>To datatype</th>
</tr>
</thead>
<tbody>
<tr>
<td>NUMERIC</td>
<td>CHARACTER</td>
</tr>
<tr>
<td>CHARACTER</td>
<td>DATE, TIME, TIMESTAMP</td>
</tr>
<tr>
<td>TIMESTAMP</td>
<td>DATE, TIME, CHARACTER</td>
</tr>
<tr>
<td>DATE</td>
<td>TIMESTAMP, CHARACTER</td>
</tr>
<tr>
<td>TIME</td>
<td>TIMESTAMP, CHARACTER</td>
</tr>
</tbody>
</table>

\textbf{TABLE 6.9} Compatible datatypes for \texttt{CAST()}

An error results if a given datatype cannot be converted into the datatype specified in \texttt{CAST()}.

Using \texttt{UPPER()} on text data

The \texttt{UPPER()} function can be used in SELECT, INSERT, UPDATE, or DELETE operations to force character and Blob text data to uppercase. For example, an application that prompts a user for a department name might want to ensure that all department names are stored in uppercase to simplify data retrieval later. The following code illustrates how \texttt{UPPER()} would be used in the \texttt{INSERT} statement to guarantee a user's entry is uppercase:

\[
\begin{align*}
\texttt{EXEC SQL} \\
\texttt{BEGIN DECLARE SECTION;} \\
\texttt{\hspace{1cm} char response[26];} \\
\texttt{EXEC SQL} \\
\texttt{\hspace{1cm} END DECLARE SECTION;}
\end{align*}
\]
printf("Enter new department name: ");
response[0] = '\0';
gets(response);
if (response)
    EXEC SQL
        INSERT INTO DEPARTMENT(DEPT_NO, DEPARTMENT)
            VALUES(GEN_ID(GDEPT_NO, 1), UPPER(:response));

The next statement illustrates how UPPER() can be used in a SELECT statement to affect both the appearance of values retrieved, and to affect its search condition:
EXEC SQL
    SELECT DEPT_NO, UPPER(DEPARTMENT)
    FROM DEPARTMENT
    WHERE UPPER(DEPARTMENT) STARTING WITH 'A';

Understanding data retrieval with SELECT
The SELECT statement handles all queries in SQL. SELECT can retrieve one or more rows from a table, and can return entire rows, or a subset of columns from each row, often referred to as a projection. Optional SELECT syntax can be used to specify search criteria that restrict the number of rows returned, to select rows with unknown values, to select rows through a view, and to combine rows from two or more tables.

At a minimum, every SELECT statement must:
- List which columns to retrieve from a table. The column list immediately follows the SELECT keyword.
- Name the table to search in a FROM clause.

Singleton selects must also include both an INTO clause to specify the host variables into which retrieved values should be stored, and a WHERE clause to specify the search conditions that cause only a single row to be returned.

The following SELECT retrieves three columns from a table and stores the values in three host-language variables:
EXEC SQL
    SELECT EMP_NO, FIRSTNAME, LASTNAME
    INTO :emp_no, :fname, :lname
    FROM EMPLOYEE WHERE EMP_NO = 1888;
Tip  Host variables must be declared in a program before they can be used in SQL statements. For more information about declaring host variables, see Chapter 2, “Application Requirements.”

The following table lists all SELECT statement clauses, in the order that they are used, and prescribes their use in singleton and multi-row selects:

<table>
<thead>
<tr>
<th>Clause</th>
<th>Purpose</th>
<th>Singleton SELECT</th>
<th>Multi-row SELECT</th>
</tr>
</thead>
<tbody>
<tr>
<td>SELECT</td>
<td>Lists columns to retrieve.</td>
<td>Required</td>
<td>Required</td>
</tr>
<tr>
<td>INTO</td>
<td>Lists host variables for storing retrieved columns.</td>
<td>Required</td>
<td>Not allowed</td>
</tr>
<tr>
<td>FROM</td>
<td>Identifies the tables to search for values.</td>
<td>Required</td>
<td>Required</td>
</tr>
<tr>
<td>WHERE</td>
<td>Specifies the search conditions used to restrict retrieved rows to a subset of all available rows. A WHERE clause can contain its own SELECT statement, referred to as a subquery.</td>
<td>Optional</td>
<td>Optional</td>
</tr>
<tr>
<td>GROUP BY</td>
<td>Groups related rows based on common column values. Used in conjunction with HAVING.</td>
<td>Optional</td>
<td>Optional</td>
</tr>
<tr>
<td>HAVING</td>
<td>Restricts rows generated by GROUP BY to a subset of those rows.</td>
<td>Optional</td>
<td>Optional</td>
</tr>
<tr>
<td>UNION</td>
<td>Combines the results of two or more SELECT statements to produce a single, dynamic table without duplicate rows.</td>
<td>Optional</td>
<td>Optional</td>
</tr>
<tr>
<td>PLAN</td>
<td>Specifies the query plan that should be used by the query optimizer instead of one it would normally choose.</td>
<td>Optional</td>
<td>Optional</td>
</tr>
<tr>
<td>ORDER BY</td>
<td>Specifies the sort order of rows returned by a SELECT, either ascending (ASC), the default, or descending (DESC).</td>
<td>Optional</td>
<td>Optional</td>
</tr>
<tr>
<td>FOR UPDATE</td>
<td>Specifies columns listed after the SELECT clause of a DECLARE CURSOR statement that can be updated using a WHERE CURRENT OF clause.</td>
<td>Not allowed</td>
<td>Optional</td>
</tr>
</tbody>
</table>

TABLE 6.10 SELECT statement clauses

Using each of these clauses with SELECT is described in the following sections, after which using SELECT directly to return a single row, and using SELECT within a DECLARE CURSOR statement to return multiple rows are described in detail. For a complete overview of SELECT syntax, see the Language Reference.
Listing columns to retrieve with SELECT

A list of columns to retrieve must always follow the SELECT keyword in a SELECT statement. The SELECT keyword and its column list is called a SELECT clause.

- **Retrieving a list of columns**

To retrieve a subset of columns for a row of data, list each column by name, in the order of desired retrieval, and separate each column name from the next by a comma. Operations that retrieve a subset of columns are often called *projections*.

For example, the following SELECT retrieves three columns:

```sql
EXEC SQL
    SELECT EMP_NO, FIRSTNAME, LASTNAME
    INTO :emp_no, :fname, :lname
    FROM EMPLOYEE WHERE EMP_NO = 2220;
```

- **Retrieving all columns**

To retrieve all columns of data, use an asterisk (*) instead of listing any columns by name. For example, the following SELECT retrieves every column of data for a single row in the EMPLOYEE table:

```sql
EXEC SQL
    SELECT *
    INTO :emp_no, :fname, :lname, :phone_ext, :hire, :dept_no,
         :job_code, :job_grade, :job_country, :salary, :full_name
    FROM EMPLOYEE WHERE EMP_NO = 1888;
```

**IMPORTANT** You must provide one host variable for each column returned by a query.

**ELIMINATING DUPLICATE COLUMNS WITH DISTINCT**

In a query returning multiple rows, it may be desirable to eliminate duplicate columns. For example, the following query, meant to determine if the EMPLOYEE table contains employees with the last name, SMITH, might locate many such rows:

```sql
EXEC SQL
    DECLARE SMITH CURSOR FOR
    SELECT LAST_NAME
    FROM EMPLOYEE
    WHERE LAST_NAME = 'Smith';
```

To eliminate duplicate columns in such a query, use the DISTINCT keyword with SELECT. For example, the following SELECT yields only a single instance of “Smith”:
EXEC SQL
DECLARE SMITH CURSOR FOR
   SELECT DISTINCT LAST_NAME
   FROM EMPLOYEE
   WHERE LAST_NAME = 'Smith';

DISTINCT affects all columns listed in a SELECT statement.

- **Retrieving aggregate column information**

SELECT can include aggregate functions, functions that calculate or retrieve a single, collective numeric value for a column or expression based on each qualifying row in a query rather than retrieving each value separately. The following table lists the aggregate functions supported by InterBase:

<table>
<thead>
<tr>
<th>Function</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVG()</td>
<td>Calculates the average numeric value for a set of values.</td>
</tr>
<tr>
<td>MIN()</td>
<td>Retrieves the minimum value in a set of values.</td>
</tr>
<tr>
<td>MAX()</td>
<td>Retrieves the maximum value in a set of values.</td>
</tr>
<tr>
<td>SUM()</td>
<td>Calculates the total of numeric values in a set of values.</td>
</tr>
<tr>
<td>COUNT()</td>
<td>Calculates the number of rows that satisfy the query's search condition (specified in the WHERE clause).</td>
</tr>
</tbody>
</table>

**TABLE 6.11 Aggregate functions in SQL**

For example, the following query returns the average salary for all employees in the EMPLOYEE table:

EXEC SQL
   SELECT AVG(SALARY)
       INTO :avg_sal
   FROM EMPLOYEE;

The following SELECT returns the number of qualifying rows it encounters in the EMPLOYEE table, both the maximum and minimum employee number of employees in the table, and the total salary of all employees in the table:

EXEC SQL
   SELECT COUNT(*), MAX(EMP_NO), MIN(EMP_NO), SUM(SALARY)
       INTO :counter, :maxno, :minno, :total_salary
   FROM EMPLOYEE;
If a field value involved in an aggregate calculation is NULL or unknown, the entire row is automatically excluded from the calculation. Automatic exclusion prevents averages from being skewed by meaningless data.

**Note** Aggregate functions can also be used to calculate values for groups of rows. The resulting value is called a *group aggregate*. For more information about using group aggregates, see “Grouping rows with GROUP BY” on page 139.

### Multi-table SELECT statements

When data is retrieved from multiple tables, views, and select procedures, the same column name may appear in more than one table. In these cases, the SELECT statement must contain enough information to distinguish like-named columns from one another.

To distinguish column names in multiple tables, precede those columns with one of the following qualifiers in the SELECT clause:

- The name of the table, followed by a period. For example, EMPLOYEE.EMP_NO identifies a column named EMP_NO in the EMPLOYEE table.
- A table correlation name (alias) followed by a period. For example, if the correlation name for the EMPLOYEE table is EMP, then EMP.EMP_NO identifies a column named EMP_NO in the EMPLOYEES table.

Correlation names can be declared for tables, views, and select procedures in the **FROM** clause of the SELECT statement. For more information about declaring correlation names, and for examples of their use, see “Declaring and using correlation names” on page 134.

### Specifying transaction names

InterBase enables an SQL application to run many simultaneous transactions if:

- Each transaction is first named with a **SET TRANSACTION** statement.
- Each data manipulation statement (SELECT, INSERT, UPDATE, DELETE) specifies a **TRANSACTION** clause that identifies the name of the transaction under which it operates.
- SQL statements are not dynamic.

In **SELECT**, the **TRANSACTION** clause intervenes between the **SELECT** keyword and the column list, as in the following syntax fragment:

```
SELECT TRANSACTION name <col> [, <col> ...]
```

The **TRANSACTION** clause is optional in single-transaction programs or in programs where only one transaction is open at a time. It must be used in a multi-transaction program. For example, the following **SELECT** is controlled by the transaction, T1:

```sql
EXEC SQL
```
SELECT TRANSACTION T1:
    COUNT(*), MAX(EMP_NO), MIN(EMP_NO), SUM(SALARY)
    INTO :counter, :maxno, :minno, :total_salary
    FROM EMPLOYEE;

For a complete discussion of transaction handling and naming, see Chapter 4, “Working with Transactions.”

---

**Specifying host variables with INTO**

A singleton select returns data to a list of host-language variables specified by an INTO clause in the SELECT statement. The INTO clause immediately follows the list of table columns from which data is to be extracted. Each host variable in the list must be preceded by a colon (:) and separated from the next by a comma.

The host-language variables in the INTO clause must already have been declared before they can be used. The number, order, and datatype of host-language variables must correspond to the number, order, and datatype of the columns retrieved. Otherwise, overflow or data conversion errors may occur.

For example, the following C program fragment declares three host variables, `lname`, `fname`, and `salary`. Two, `lname`, and `fname`, are declared as character arrays; `salary` is declared as a long integer. The SELECT statement specifies that three columns of data are to be retrieved, while the INTO clause specifies the host variables into which the data should be read.

```c
EXEC SQL
    BEGIN DECLARE SECTION;
    long salary;
    char lname[20], fname[15];
EXEC SQL
    END DECLARE SECTION;
    
EXEC SQL
    SELECT LAST_NAME, FIRST_NAME, SALARY
    INTO :lanem, :fname, :salary
    FROM EMPLOYEE
    WHERE LNAME = 'Smith';
```
Note In a multi-row select, the INTO clause is part of the FETCH statement, not the SELECT statement. For more information about the INTO clause in FETCH, see “Fetching rows with a cursor” on page 147.

Listing tables to search with FROM

The FROM clause is required in a SELECT statement. It identifies the tables, views, or select procedures from which data is to be retrieved. The complete syntax of the FROM clause is:

```
FROM table | view | procedure [alias] [, table | view | procedure [alias] ...]
```

There must be at least one table, view, or select procedure name following the FROM keyword. When retrieving data from multiple sources, each source must be listed, assigned an alias, and separated from the next with a comma. For more information about select procedures, see Chapter 10, “Working with Stored Procedures.”

- Listing a single table or view

The FROM clause in the following SELECT specifies a single table, EMPLOYEE, from which to retrieve data:

```
EXEC SQL
  SELECT LAST_NAME, FIRST_NAME, SALARY
  INTO :lanem, :fname, :salary
  FROM EMPLOYEE
  WHERE LNAME = 'Smith';
```

Use the same INTO clause syntax to specify a view or select procedure as the source for data retrieval instead of a table. For example, the following SELECT specifies a select procedure, MVIEW, from which to retrieve data. MVIEW returns information for all managers whose last names begin with the letter “M,” and the WHERE clause narrows the rows returned to a single row where the DEPT_NO column is 430:

```
EXEC SQL
  SELECT DEPT_NO, LAST_NAME, FIRST_NAME, SALARY
  INTO :lname, :fname, :salary
  FROM MVIEW
  WHERE DEPT_NO = 430;
```

For more information about select procedures, see Chapter 10, “Working with Stored Procedures.”
**Listing multiple tables**

To retrieve data from multiple tables, views, or select procedures, include all sources in the FROM clause, separating sources from one another by commas.

There are two different possibilities to consider when working with multiple data sources:

1. The name of each referenced column is unique across all tables.
2. The names of one or more referenced columns exist in two or more tables.

In the first case, just use the column names themselves to reference the columns. For example, the following query returns data from two tables, DEPARTMENT, and EMPLOYEE:

```sql
EXEC SQL
SELECT DEPARTMENT, DEPT_NO, LAST_NAME, FIRST_NAME, EMP_NO
INTO :dept_name, :dept_no, :lname, :fname, :empno
FROM DEPARTMENT, EMPLOYEE
WHERE DEPT_NO = 'Publications' AND MNGR_NO = EMP_NO;
```

In the second case, column names that occur in two or more tables must be distinguished from one another by preceding each column name with its table name and a period in the SELECT clause. For example, if an EMP_NO column exists in both the DEPARTMENT and EMPLOYEE then the previous query must be recast as follows:

```sql
EXEC SQL
SELECT DEPARTMENT, DEPT_NO, LAST_NAME, FIRST_NAME,
EMPLOYEE.EMP_NO
INTO :dept_name, :dept_no, :lname, :fname, :empno
FROM DEPARTMENT, EMPLOYEE
WHERE DEPT_NO = 'Publications' AND
DEPARTMENT.EMP_NO = EMPLOYEE.EMP_NO;
```

For more information about the SELECT clause, see “Listing columns to retrieve with SELECT” on page 128.

**IMPORTANT** For queries involving joins, column names can be qualified by correlation names, brief alternate names, or aliases, that are assigned to each table in a FROM clause and substituted for them in other SELECT statement clauses when qualifying column names. Even when joins are not involved, assigning and using correlation names can reduce the length of complex queries.
Declaring and using correlation names

A correlation name, or alias, is a temporary variable that represents a table name. It can contain up to 31 alphanumeric characters, dollar signs ($), and underscores (_), but must always start with an alphabetic character. Using brief correlation names reduces typing of long queries. Correlation names must be substituted for actual table names in joins, and can be substituted for them in complex queries.

A correlation name is associated with a table in the FROM clause; it replaces table names to qualify column names everywhere else in the statement. For example, to associate the correlation name, DEPT with the DEPARTMENT table, and EMP, with the EMPLOYEES table, a FROM clause might appear as:

FROM DEPARTMENT DEPT, EMPLOYEE EMP

Like an actual table name, a correlation name is used to qualify column names wherever they appear in a SELECT statement. For example, the following query employs the correlation names, DEPT, and EMP, previously described:

EXEC SQL
    SELECT DEPARTMENT, DEPT_NO, LAST_NAME, FIRST_NAME,
           EMPLOYEE.EMP_NO
    INTO :dept_name, :dept_no, :lname, :fname, :empno
    FROM DEPARTMENT DEPT, EMPLOYEE EMP
    WHERE DEPT_NO = 'Publications' AND DEPT.EMP_NO = EMP.EMP_NO;

For more information about the SELECT clause, see “Listing columns to retrieve with SELECT” on page 128.

Restricting row retrieval with WHERE

In a query, the WHERE clause specifies the data a row must (or must not) contain to be retrieved.

In singleton selects, where a query must only return one row, WHERE is mandatory unless a select procedure specified in the FROM clause returns only one row itself.

In SELECT statements within DECLARE CURSOR statements, the WHERE clause is optional. If the WHERE clause is omitted, a query returns all rows in the table. To retrieve a subset of rows in a table, a cursor declaration must include a WHERE clause.

The simple syntax for WHERE is:

WHERE <search_condition>

For example, the following simple WHERE clause tests a row to see if the DEPARTMENT column is “Publications”:
What is a search condition?
Because the WHERE clause specifies the type of data a query is searching for it is often called a search condition. A query examines each row in a table to see if it meets the criteria specified in the search condition. If it does, the row qualifies for retrieval.

When a row is compared to a search condition, one of three values is returned:
- **True**: A row meets the conditions specified in the WHERE clause.
- **False**: A row fails to meet the conditions specified in the WHERE clause.
- **Unknown**: A column tested in the WHERE clause contains an unknown value that could not be evaluated because of a NULL comparison.

Most search conditions, no matter how complex, evaluate to True or False. An expression that evaluates to True or False—like the search condition in the WHERE clause—is called a Boolean expression.

Structure of a search condition
A typical simple search condition compares a value in one column against a constant or a value in another column. For example, the following WHERE clause tests a row to see if a field equals a hard-coded constant:

```
WHERE DEPARTMENT = 'Publications'
```

This search condition has three elements: a column name, a comparison operator (the equal sign), and a constant. Most search conditions are more complex than this. They involve additional elements and combinations of simple search conditions. The following table describes expression elements that can be used in search conditions:
### Elements of WHERE clause SEARCH conditions

<table>
<thead>
<tr>
<th>Element</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column names</td>
<td>Columns from tables listed in the FROM clause, against which to search or</td>
</tr>
<tr>
<td></td>
<td>compare values.</td>
</tr>
<tr>
<td>Host-language variables</td>
<td>Program variables containing changeable values. When used in a SELECT,</td>
</tr>
<tr>
<td></td>
<td>host-language variables must be preceded by a colon (:).</td>
</tr>
<tr>
<td>Constants</td>
<td>Hard-coded numbers or quoted strings, like 507 or “Tokyo”.</td>
</tr>
<tr>
<td>Concatenation operators</td>
<td></td>
</tr>
<tr>
<td>Arithmetic operators</td>
<td>+, −, *, and /, used to calculate and evaluate search condition values.</td>
</tr>
<tr>
<td>Logical operators</td>
<td>Keywords, NOT, AND, and OR, used within simple search conditions, or to</td>
</tr>
<tr>
<td></td>
<td>combine simple search conditions to make complex searches. A logical</td>
</tr>
<tr>
<td></td>
<td>operation evaluates to true or false.</td>
</tr>
<tr>
<td>Comparison operators</td>
<td>&lt;, &gt;, &lt;=, &gt;=, =, and &lt;&gt;, used to compare a value on the left side of the</td>
</tr>
<tr>
<td></td>
<td>operator to another on the right. A comparative operation evaluates to</td>
</tr>
<tr>
<td></td>
<td>True or False.</td>
</tr>
<tr>
<td></td>
<td>Other, more specialized comparison operators include ALL, ANY, BETWEEN,</td>
</tr>
<tr>
<td></td>
<td>CONTAINING, EXISTS, IN, IS, LIKE, NULL, SINGULAR, SOME, and STARTING WITH.</td>
</tr>
<tr>
<td></td>
<td>These operators can evaluate to True, False, or Unknown.</td>
</tr>
<tr>
<td>COLLATE clause</td>
<td>Comparisons of CHAR and VARCHAR values can sometimes take advantage of a</td>
</tr>
<tr>
<td></td>
<td>COLLATE clause to force the way text values are compared.</td>
</tr>
<tr>
<td>Stored procedures</td>
<td>Reusable SQL statement blocks that can receive and return parameters,</td>
</tr>
<tr>
<td></td>
<td>and that are stored as part of a database's metadata. For more information</td>
</tr>
<tr>
<td></td>
<td>about stored procedures in queries, see Chapter 10, “Working with Stored</td>
</tr>
<tr>
<td></td>
<td>Procedures.”</td>
</tr>
<tr>
<td>Subqueries</td>
<td>A SELECT statement nested within the WHERE clause to return or calculate</td>
</tr>
<tr>
<td></td>
<td>values against which rows searched by the main SELECT statement are</td>
</tr>
<tr>
<td></td>
<td>compared. For more information about subqueries, see “Using subqueries” on</td>
</tr>
<tr>
<td></td>
<td>page 161.</td>
</tr>
<tr>
<td>Parentheses</td>
<td>Group related parts of search conditions which should be processed</td>
</tr>
<tr>
<td></td>
<td>separately to produce a single value which is then used to evaluate the</td>
</tr>
<tr>
<td></td>
<td>search condition. Parenthetical expressions can be nested.</td>
</tr>
</tbody>
</table>

**TABLE 6.12** Elements of WHERE clause SEARCH conditions
Complex search conditions can be constructed by combining simple search conditions in
different ways. For example, the following WHERE clause uses a column name, three
constants, three comparison operators, and a set of grouping parentheses to retrieve only
those rows for employees with salaries between $60,000 and $120,000:

```
WHERE DEPARTMENT = 'Publications' AND
(SALARY > 60000 AND SALARY < 120000)
```

Search conditions in WHERE clauses often contain nested SELECT statements, or
subqueries. For example, in the following query, the WHERE clause contains a subquery
that uses the aggregate function, AVG(), to retrieve a list of all departments with
bigger-than-average salaries:

```
EXEC SQL
DECLARE WELL_PAID CURSOR FOR
SELECT DEPT_NO
INTO :wellpaid
FROM DEPARTMENT
WHERE SALARY > (SELECT AVG(SALARY) FROM DEPARTMENT);
```

For a general discussion of building search conditions from SQL expressions, see
“Understanding SQL expressions” on page 110. For more information about using
subqueries to specify search conditions, see “Using subqueries” on page 161. For more
information about aggregate functions, see “Retrieving aggregate column
information” on page 129.

- **Collation order in comparisons**

  When CHAR or VARCHAR values are compared in a WHERE clause, it can be necessary to
  specify a collation order for the comparisons if the values being compared use different
collation orders.

  To specify the collation order to use for a value during a comparison, include a COLLATE
clause after the value. For example, in the following WHERE clause fragment from an
embedded application, the value to the left of the comparison operator is forced to be
compared using a specific collation:

```
WHERE LNAME COLLATE FR_CA = :lname_search;
```

For more information about collation order and a list of collations available to InterBase,
see the *Data Definition Guide*. 
Sorting rows with ORDER BY

By default, a query retrieves rows in the exact order it finds them in a table, and because internal table storage is unordered, retrieval, too, is likely to be unordered. To specify the order in which rows are returned by a query, use the optional ORDER BY clause at the end of a SELECT statement.

ORDER BY retrieves rows based on a column list. Every column in the ORDER BY clause must also appear somewhere in the SELECT clause at the start of the statement. Each column can optionally be ordered in ascending order (ASC, the default), or descending order (DESC). The complete syntax of ORDER BY is:

```
ORDER BY col [COLLATE collation] [ASC | DESC]
[, col [COLLATE collation] [ASC | DESC] ...];
```

For example, the following cursor declaration orders output based on the LAST_NAME column. Because DESC is specified in the ORDER BY clause, employees are retrieved from Z to A:

```
EXEC SQL
  DECLARE PHONE_LIST CURSOR FOR
  SELECT LAST_NAME, FIRST_NAME, PHONE_EXT
  FROM EMPLOYEE
  WHERE PHONE_EXT IS NOT NULL
  ORDER BY LAST_NAME DESC, FIRST_NAME;
```

**ORDER BY with multiple columns**

If more than one column is specified in an ORDER BY clause, rows are first arranged by the values in the first column. Then rows that contain the same first-column value are arranged according to the values in the second column, and so on. Each ORDER BY column can include its own sort order specification.

**IMPORTANT** In multi-column sorts, after a sort order is specified, it applies to all subsequent columns until another sort order is specified, as in the previous example. This attribute is sometimes called *sticky sort order*. For example, the following cursor declaration orders retrieval by LAST_NAME in descending order, then refines it alphabetically within LAST_NAME groups by FIRST_NAME in ascending order:

```
EXEC SQL
  DECLARE PHONE_LIST CURSOR FOR
  SELECT LAST_NAME, FIRST_NAME, PHONE_EXT
  FROM EMPLOYEE
  WHERE PHONE_EXT IS NOT NULL
  ORDER BY LAST_NAME DESC, FIRST_NAME ASC;
```
Collation order in an ORDER BY clause

When CHAR or VARCHAR columns are ordered in a SELECT statement, it can be necessary to specify a collation order for the ordering, especially if columns used for ordering use different collation orders.

To specify the collation order to use for ordering a column in the ORDER BY clause, include a COLLATE clause after the column name. For example, in the following ORDER BY clause, a different collation order for each of two columns is specified:

```sql
ORDER BY LNAME COLLATE FR_CA, FNAME COLLATE FR_FR;
```

For more information about collation order and a list of available collations in InterBase, see the Data Definition Guide.

Grouping rows with GROUP BY

The optional GROUP BY clause enables a query to return summary information about groups of rows that share column values instead of returning each qualifying row. The complete syntax of GROUP BY is:

```sql
GROUP BY col [COLLATE collation] [, col [COLLATE collation] ...]
```

For example, consider two cursor declarations. The first declaration returns the names of all employees each department, and arranges retrieval in ascending alphabetic order by department and employee name.

```sql
EXEC SQL
   DECLARE DEPT_EMP CURSOR FOR
      SELECT DEPARTMENT, LAST_NAME, FIRST_NAME
      FROM DEPARTMENT D, EMPLOYEE E
      WHERE D.DEPT_NO = E.DEPT_NO
      ORDER BY DEPARTMENT, LAST_NAME, FIRST_NAME;
```

In contrast, the next cursor illustrates the use of aggregate functions with GROUP BY to return results known as group aggregates. It returns the average salary of all employees in each department. The GROUP BY clause assures that average salaries are calculated and retrieved based on department names, while the ORDER BY clause arranges retrieved rows alphabetically by department name.

```sql
EXEC SQL
   DECLARE AVG_DEPT_SAL CURSOR FOR
      SELECT DEPARTMENT, AVG(SALARY)
      FROM DEPARTMENT D, EMPLOYEE E
      WHERE D.DEPT_NO = E.DEPT_NO
```
GROUP BY DEPARTMENT
ORDER BY DEPARTMENT;

- **Collation order in a GROUP BY clause**

When CHAR or VARCHAR columns are grouped in a SELECT statement, it can be necessary to specify a collation order for the grouping, especially if columns used for grouping use different collation orders.

To specify the collation order to use for grouping columns in the GROUP BY clause, include a COLLATE clause after the column name. For example, in the following GROUP BY clause, the collation order for two columns is specified:

```
GROUP BY LNAME COLLATE FR_CA, FNAME COLLATE FR_CA;
```

For more information about collation order and a list of collation orders available in InterBase, see the *Data Definition Guide*.

- **Limitations of GROUP BY**

When using GROUP BY, be aware of the following limitations:

- Each column name that appears in a GROUP BY clause must also be specified in the SELECT clause.
- **GROUP BY** cannot specify a column whose values are derived from a mathematical, aggregate, or user-defined function.
- **GROUP BY** cannot be used in SELECT statements that:
  - Contain an INTO clause (singleton selects).
  - Use a subquery with a FROM clause which references a view whose definition contains a GROUP BY or HAVING clause.
- For each SELECT clause in a query, including subqueries, there can only be one GROUP BY clause.

---

### Restricting grouped rows with HAVING

Just as a WHERE clause reduces the number of rows returned by a SELECT clause, the HAVING clause can be used to reduce the number of rows returned by a GROUP BY clause. The syntax of HAVING is:

```
HAVING <search_condition>
```
HAVING uses search conditions that are like the search conditions that can appear in the WHERE clause, but with the following restrictions:

- Each search condition usually corresponds to an aggregate function used in the SELECT clause.
- The FROM clause of a subquery appearing in a HAVING clause cannot name any table or view specified in the main query's FROM clause.
- A correlated subquery cannot be used in a HAVING clause.

For example, the following cursor declaration returns the average salary for all employees in each department. The GROUP BY clause assures that average salaries are calculated and retrieved based on department names. The HAVING clause restricts retrieval to those groups where the average salary is greater than 60,000, while the ORDER BY clause arranges retrieved rows alphabetically by department name.

EXEC SQL
DECLARE SIXTY_THOU CURSOR FOR
SELECT DEPARTMENT, AVG(SALARY)
FROM DEPARTMENT D, EMPLOYEE E
WHERE D.DEPT_NO = E.DEPT_NO
GROUP BY DEPARTMENT
HAVING AVG(SALARY) > 60000
ORDER BY DEPARTMENT;

Note: HAVING can also be used without GROUP BY. In this case, all rows retrieved by a SELECT are treated as a single group, and each column named in the SELECT clause is normally operated on by an aggregate function.

For more information about search conditions, see “Restricting row retrieval with WHERE” on page 134. For more information about subqueries, see “Using subqueries” on page 161.

Appending tables with UNION

Sometimes two or more tables in a database are identically structured, or have columns that contain similar data. Where table structures overlap, information from those tables can be combined to produce a single results table that returns a projection for every qualifying row in both tables. The UNION clause retrieves all rows from each table, appends one table to the end of another, and eliminates duplicate rows.

Unions are commonly used to perform aggregate operations on tables.
The syntax for UNION is:

```
UNION SELECT col [, col ...] | * FROM <tableref> [, <tableref> ...]
```

For example, three tables, CITIES, COUNTRIES, and NATIONAL_PARKS, each contain the names of cities. Assuming triggers have not been created that ensure that a city entered in one table is also entered in the others to which it also applies, UNION can be used to retrieve the names of all cities that appear in any of these tables.

```
EXEC SQL
DECLARE ALLCITIES CURSOR FOR
SELECT CIT.CITY FROM CITIES CIT
UNION SELECT COU.CAPITAL FROM COUNTRIES COU
UNION SELECT N.PARKCITY FROM NATIONAL_PARKS N;
```

**Tip** If two or more tables share entirely identical structures—similarly named columns, identical datatypes, and similar data values in each column—UNION can return all rows for each table by substituting an asterisk (*) for specific column names in the SELECT clauses of the UNION.

---

**Specifying a query plan with PLAN**

To process a SELECT statement, InterBase uses an internal algorithm, called the *query optimizer*, to determine the most efficient plan for retrieving data. The most efficient retrieval plan also results in the fastest retrieval time. Occasionally the optimizer may choose a plan that is less efficient. For example, when the number of rows in a table grows sufficiently large, or when many duplicate rows are inserted or deleted from indexed columns in a table, but the index's selectivity is not recomputed, the optimizer might choose a less efficient plan.

For these occasions, SELECT provided an optional PLAN clause that enables a knowledgeable programmer to specify a retrieval plan. A query plan is built around the availability of indexes, the way indexes are joined or merged, and a chosen access method.

To specify a query plan, use the following PLAN syntax:

```
PLAN <plan_expr>
<plan_expr> =
[JOIN | [SORT] MERGE] (<plan_item> | <plan_expr>
[, <plan_item> | <plan_expr> ...])
<plan_item> = { table | alias}
NATURAL | INDEX ( <index> [, <index> ...]) | ORDER <index>
```
The PLAN syntax enables specifying a single table, or a join of two or more tables in a single pass. Plan expressions can be nested in parentheses to specify any combination of joins.

During retrieval, information from different tables is joined to speed retrieval. If indexes are defined for the information to be joined, then these indexes are used to perform a join. The optional JOIN keyword can be used to document this type of operation. When no indexes exist for the information to join, retrieval speed can be improved by specifying SORT MERGE instead of JOIN.

A plan_item is the name of a table to search for data. If a table is used more than once in a query, aliases must be used to distinguish them in the PLAN clause. Part of the plan_item specification indicates the way that rows should be accessed. The following choices are possible:

- **NATURAL**, the default order, specifies that rows are accessed sequentially in no defined order. For unindexed items, this is the only option.
- **INDEX** specifies that one or more indexes should be used to access items. All indexes to be used must be specified. If any Boolean or join terms remain after all indexes are used, they will be evaluated without benefit of an index. If any indexes are specified that cannot be used, an error is returned.
- **ORDER** specifies that items are to be sorted based on a specified index.

---

**Selecting a single row**

An operation that retrieves a single row of data is called a singleton select. To retrieve a single row from a table, to retrieve a column defined with a unique index, or to select an aggregate value like COUNT() or AVG() from a table, use the following SELECT statement syntax:

```
SELECT <col> [, <col> ...]
    INTO :variable [, :variable ...]
FROM table
WHERE <search_condition>;
```

The mandatory INTO clause specifies the host variables where retrieved data is copied for use in the program. Each host variable's name must be preceded by a colon (:). For each column retrieved, there must be one host variable of a corresponding datatype. Columns are retrieved in the order they are listed in the SELECT clause, and are copied into host variables in the order the variables are listed in the INTO clause.
The WHERE clause must specify a search condition that guarantees that only one row is retrieved. If the WHERE clause does not reduce the number of rows returned to a single row, the SELECT fails.

**IMPORTANT** To select data from a table, a user must have SELECT privilege for a table, or a stored procedure invoked by the user's application must have SELECT privileges for the table.

For example, the following SELECT retrieves information from the DEPARTMENT table for the department, Publications:

```sql
EXEC SQL
SELECT DEPARTMENT, DEPT_NO, HEAD_DEPT, BUDGET, LOCATION, PHONE_NO
INTO :deptname, :dept_no, :manager, :budget, :location, :phone
FROM DEPARTMENT
WHERE DEPARTMENT = 'Publications';
```

When SQL retrieves the specified row, it copies the value in DEPARTMENT to the host variable, `deptname`, copies the value in DEPT_NO to `dept_no`, copies the value in HEAD_DEPT to `manager`, and so on.

---

**Selecting multiple rows**

Most queries specify search conditions that retrieve more than one row. For example, a query that asks to see all employees in a company that make more than $60,000 can retrieve many employees.

Because host variables can only hold a single column value at a time, a query that returns multiple rows must build a temporary table in memory, called a *results table*, from which rows can then be extracted and processed, one at a time, in sequential order. SQL keeps track of the next row to process in the results table by establishing a pointer to it, called a *cursor*.

**IMPORTANT** In dynamic SQL (DSQL), the process for creating a query and retrieving data is somewhat different. For more information about multi-row selection in DSQL, see "Selecting multiple rows in DSQL" on page 152.

To retrieve multiple rows into a results table, establish a cursor into the table, and process individual rows in the table, SQL provides the following sequence of statements:

1. DECLARE CURSOR establishes a name for the cursor and specifies the query to perform.
2. OPEN executes the query, builds the results table, and positions the cursor at the start of the table.
3. **FETCH** retrieves a single row at a time from the results table into host variables for program processing.

4. **CLOSE** releases system resources when all rows are retrieved.

**IMPORTANT** To select data from a table, a user must have SELECT privilege for a table, or a stored procedure invoked by the user's application must have SELECT privilege for it.

---

**Declaring a cursor**

To declare a cursor and specify rows of data to retrieve, use the DECLARE CURSOR statement. DECLARE CURSOR is a descriptive, non-executable statement. InterBase uses the information in the statement to prepare system resources for the cursor when it is opened, but does not actually perform the query. Because DECLARE CURSOR is non-executable, SQLCODE is not assigned when this statement is used.

The syntax for DECLARE CURSOR is:

```
DECLARE cursorname CURSOR FOR
    SELECT <col> [, <col> ...]
    FROM table [, <table> ...]
    WHERE <search_condition>
    [GROUP BY col [, col ...]]
    [HAVING <search_condition>]
    [ORDER BY col [ASC | DESC] [, col ...] [ASC | DESC]
     | FOR UPDATE OF col [, col ...]];  
```

The `cursorname` is used in subsequent OPEN, FETCH, and CLOSE statements to identify the active cursor.

With the following exceptions, the SELECT statement inside a DECLARE CURSOR is similar to a stand-alone SELECT:

- A SELECT in a DECLARE CURSOR cannot include an INTO clause.
- A SELECT in a DECLARE CURSOR can optionally include either an ORDER BY clause or a FOR UPDATE clause.

For example, the following statement declares a cursor:

```
EXEC SQL
    DECLARE TO_BE_HIRED CURSOR FOR
        SELECT D.DEPARTMENT, D.LOCATION, P.DEPARTMENT
        FROM DEPARTMENT D, DEPARTMENT P
        WHERE D.MNGR_NO IS NULL
        AND D.HEAD_DEPT = P.DEPT_NO;
```
Updating through cursors

In many applications, data retrieval and update may be interdependent. DECLARE CURSOR supports an optional FOR UPDATE clause that optionally lists columns in retrieved rows that can be modified. For example, the following statement declares such a cursor:

```sql
EXEC SQL
DECLARE H CURSOR FOR
    SELECT CUST_NO
    FROM CUSTOMER
    WHERE ON_HOLD = '/*'
    FOR UPDATE OF ON_HOLD;
```

If a column list after FOR UPDATE is omitted, all columns retrieved for each row may be updated. For example, the following query enables updating for two columns:

```sql
EXEC SQL
DECLARE H CURSOR FOR
    SELECT CUST_NAME CUST_NO
    FROM CUSTOMER
    WHERE ON_HOLD = '/*';
```

For more information about updating columns through a cursor, see “Updating multiple rows” on page 171.

Opening a cursor

Before data selected by a cursor can be accessed, the cursor must be opened with the OPEN statement. OPEN activates the cursor and builds a results table. It builds the results table based on the selection criteria specified in the DECLARE CURSOR statement. The rows in the results table comprise the active set of the cursor.

For example, the following statement opens a previously declared cursor called DEPT_EMP:

```sql
EXEC SQL
OPEN DEPT_EMP;
```

When InterBase executes the OPEN statement, the cursor is positioned at the start of the first row in the results table.
Fetching rows with a cursor

Once a cursor is opened, rows can be retrieved, one at a time, from the results table by using the FETCH statement. FETCH:

1. Retrieves the next available row from the results table.
2. Copies those rows into the host variables specified in the INTO clause of the FETCH statement.
3. Advances the cursor to the start of the next available row or sets SQLCODE to 100, indicating the cursor is at the end of the results table and there are no more rows to retrieve.

The complete syntax of the FETCH statement in SQL is:

```sql
```

**IMPORTANT** In dynamic SQL (DSQL) multi-row select processing, a different FETCH syntax is used. For more information about retrieving multiple rows in DSQL, see “Fetching rows with a DSQL cursor” on page 154.

For example, the following statement retrieves a row from the results table for the DEPT_EMP cursor, and copies its column values into the host-language variables, `deptname`, `lname`, and `fname`:

```sql
EXEC SQL
    FETCH DEPT_EMP
    INTO :deptname, :lname, :fname;
```

To process each row in a results table in the same manner, enclose the FETCH statement in a host-language looping construct. For example, the following C code fetches and prints each row defined for the DEPT_EMP cursor:

```c
...
EXEC SQL
    FETCH DEPT_EMP
    INTO :deptname, :lname, :fname;
while (!SQLCODE) {
    printf("%s %s works in the %s department.\n", fname, lname, deptname);
    EXEC SQL
        FETCH DEPT_EMP
        INTO :deptname, :lname, :fname;
}
```
EXEC SQL
  CLOSE DEPT_EMP;
  ... 

Every FETCH statement should be tested to see if the end of the active set is reached. The
previous example operates in the context of a while loop that continues processing as
long as SQLCODE is zero. If SQLCODE is 100, it indicates that there are no more rows to
retrieve. If SQLCODE is less than zero, it indicates that an error occurred.

- **Retrieving indicator status**

Any column can have a NULL value, except those defined with the NOT NULL or UNIQUE
integrity constraints. Rather than store a value for the column, InterBase sets a flag
indicating the column has no assigned value.

To determine if a value returned for a column is NULL, follow each variable named in the
INTO clause with the INDICATOR keyword and the name of a short integer variable, called
an *indicator variable*, where InterBase should store the status of the NULL value flag for
the column. If the value retrieved is:

- NULL, the indicator variable is set to –1.
- Not NULL, the indicator parameter is set to 0.

For example, the following C code declares three host-language variables, department,
manager, and missing_manager, then retrieves column values into
department, manager, and a status flag for the column retrieved into manager,
missing_manager, with a FETCH from a previously declared cursor, GETCITY:

```
char department[26];
char manager[36];
short missing_manager;
```

```
FETCH GETCITY INTO :department, :manager INDICATOR :missing_manager;
```

The optional INDICATOR keyword can be omitted:

```
FETCH GETCITY INTO :department, :manager :missing_manager;
```

Often, the space between the variable that receives the actual contents of a
column and the variable that holds the status of the NULL value flag is also omitted:

```
FETCH GETCITY INTO :department, :manager:missing_manager;
```

**Note** While InterBase enforces the SQL requirement that the number of host variables in
a FETCH must equal the number of columns specified in DECLARE CURSOR, indicator
variables in a FETCH statement are *not* counted toward the column count.
Refetching rows with a cursor

The only supported cursor movement is forward in sequential order through the active set.

To revisit previously fetched rows, close the cursor and then reopen it with another OPEN statement. For example, the following statements close the DEPT_EMP cursor, then recreate it, effectively repositioning the cursor at the start of the DEPT_EMP results table:

```sql
EXEC SQL
  CLOSE DEPT_EMP;
EXEC SQL
  OPEN DEPT_EMP;
```

Closing the cursor

When the end of a cursor's active set is reached, a cursor should be closed to free up system resources. To close a cursor, use the CLOSE statement. For example, the following statement closes the DEPT_EMP cursor:

```sql
EXEC SQL
  CLOSE DEPT_EMP;
```

Programs can check for the end of the active set by examining SQLCODE, which is set to 100 to indicate there are no more rows to retrieve.

A complete cursor example

The following program declares a cursor, opens the cursor, and then loops through the cursor's active set, fetching and printing values. The program closes the cursor when all processing is finished or an error occurs.

```c
#include <stdio.h>
EXEC SQL
  BEGIN DECLARE SECTION;
    char deptname[26];
    char lname[16];
    char fname[11];
  END DECLARE SECTION;

main ()
{
```
EXEC SQL
WHENEVER SQLERROR GO TO abend;
EXEC SQL
DECLARE DEPT_EMP CURSOR FOR
    SELECT DEPARTMENT, LAST_NAME, FIRST_NAME
    FROM DEPARTMENT D, EMPLOYEE E
    WHERE D.DEPT_NO = E.DEPT_NO
    ORDER BY DEPARTMENT, LAST_NAME, FIRST_NAME;
EXEC SQL
OPEN DEPT_EMP;
EXEC SQL
FETCH DEPT_EMP
    INTO :deptname, :lname, :fname;
while (!SQLCODE)
{
    printf("%s %s works in the %s department.\n", fname,
           lname, deptname);
    EXEC SQL
    FETCH DEPT_EMP
        INTO :deptname, :lname, :fname;
}
EXEC SQL
CLOSE DEPT_EMP;
exit();

abend:
if (SQLCODE)
{
    isc_print_sqlerror();
    EXEC SQL
    ROLLBACK;
    EXEC SQL
    CLOSE DEPT_EMP;
    EXEC SQL
    DISCONNECT ALL;
    exit(1)
}
else
{
    EXEC SQL
    COMMIT;
    EXEC SQL
SELECTING MULTIPLE ROWS

DISCONNECT ALL;
exit();
}

Selecting rows with NULL values

Any column can have NULL values, except those defined with the NOT NULL or UNIQUE integrity constraints. Rather than store a value for the column, InterBase sets a flag indicating the column has no assigned value.

Use IS NULL in a WHERE clause search condition to query for NULL values. For example, some rows in the DEPARTMENT table do not have a value for the BUDGET column. Departments with no stored budget have the NULL value flag set for that column. The following cursor declaration retrieves rows for departments without budgets for possible update:

EXEC SQL
DECLARE NO_BUDGET CURSOR FOR
SELECT DEPARTMENT, BUDGET
FROM DEPARTMENT
WHERE BUDGET IS NULL
FOR UPDATE OF BUDGET;

Note To determine if a column has a NULL value, use an indicator variable. For more information about indicator variables, see “Retrieving indicator status” on page 148.

A direct query on a column containing a NULL value returns zero for numbers, blanks for characters, and 17 November 1858 for dates. For example, the following cursor declaration retrieves all department budgets, even those with NULL values, which are reported as zero:

EXEC SQL
DECLARE ALL_BUDGETS CURSOR FOR
SELECT DEPARTMENT, BUDGET
FROM DEPARTMENT
ORDER BY BUDGET DESCENDING;

Limitations on NULL values

Because InterBase treats NULL values as non-values, the following limitations on NULL values in queries should be noted:

- Rows with NULL values are sorted after all other rows.
null values are skipped by all aggregate operations, except for COUNT(*).

null values cannot be elicited by a negated test in a search condition.

null values cannot satisfy a join condition.

null values can be tested in comparisons. If a value on either side of a comparison operator is null, the result of the comparison is unknown.

For the boolean operators (not, and, and or), the following considerations are made:

null values with not always returns unknown.

null values with and return unknown unless one operand for and is false. in this latter case, false is returned.

null values with or return unknown unless one operand for or is true. in this latter case, true is returned.

For information about defining alternate null values, see the Data Definition Guide.

Selecting rows through a view

To select a subset of rows available through a view, substitute the name of the view for a table name in the FROM clause of a SELECT. for example, the following cursor produces a list of employee phone numbers based on the PHONE_VIEW view:

exec sql
   declare phone_list cursor for
   select first_name, last_name, phone_ext
   from phone_view
   where employee.dept_no = department.dept_no;

A view can be a join. Views can also be used in joins, themselves, in place of tables. For more information about views in joins, see “joining tables” on page 155.

Selecting multiple rows in DSQL

In DSQL users are usually permitted to specify queries at run time. To accommodate any type of query the user supplies, DSQL requires the use of extended SQL descriptor areas (XSQLDAS) where a query’s input and output can be prepared and described. For queries returning multiple rows, DSQL supports variations of the declare cursor, open, and fetch statements that make use of the XSQLDA.

To retrieve multiple rows into a results table, establish a cursor into the table, and process individual rows in the table. DSQL provides the following sequence of statements:
1. PREPARE establishes the user-defined query specification in the XSQLDA structure used for output.
2. DECLARE CURSOR establishes a name for the cursor and specifies the query to perform.
3. OPEN executes the query, builds the results table, and positions the cursor at the start of the table.
4. FETCH retrieves a single row at a time from the results table for program processing.
5. CLOSE releases system resources when all rows are retrieved.

The following three sections describe how to declare a DSQL cursor, how to open it, and how to fetch rows using the cursor. For more information about creating and filling XSQLDA structures, and preparing DSQL queries with PREPARE, see Chapter 13, “Using Dynamic SQL.” For more information about closing a cursor, see “Closing the cursor” on page 149.

## Declaring a DSQL cursor

DSQL must declare a cursor based on a user-defined SELECT statement. Usually, DSQL programs:

- Prompt the user for a query (SELECT).
- Store the query in a host-language variable.
- Issue a PREPARE statement that uses the host-language variable to describe the query results in an XSQLDA.
- Declare a cursor using the query alias.

The complete syntax for DECLARE CURSOR in DSQL is:

```sql
DECLARE cursorname  CURSOR FOR queryname ;
```

For example, the following C code fragment declares a string variable, `querystring`, to hold the user-defined query, gets a query from the user and stores it in `querystring`, uses `querystring` to PREPARE a query called QUERY, then declares a cursor, C, that uses QUERY:

```c
EXEC SQL
BEGIN DECLARE SECTION;
  char querystring [512];
  XSQLDA *InputSqlDa, *OutputSqlDa;
```
EXEC SQL  
   END DECLARE SECTION;  

printf("Enter query: "); /* prompt for query from user */  
gets(querystring); /* get the string, store in querystring */  
EXEC SQL  
   PREPARE QUERY INTO OutputSqlda FROM :querystring;  
EXEC SQL  
   DECLARE C CURSOR FOR QUERY;  

For more information about creating and filling XSQLDA structures, and preparing DSQL  
queries with PREPARE, see Chapter 13, "Using Dynamic SQL."

Opening a DSQL cursor  
The OPEN statement in DSQL establishes a results table from the input parameters  
specified in a previously declared and populated XSQLDA. A cursor must be opened before  
data can be retrieved. The syntax for a DSQL OPEN is:  
OPEN cursorname USING DESCRIPTOR sqldaname;  

For example, the following statement opens the cursor, C, using the XSQLDA, InputSqlda:  
EXEC SQL  
   OPEN C USING DESCRIPTOR InputSqlda;  

Fetching rows with a DSQL cursor  
DSQL uses the FETCH statement to retrieve rows from a results table. The rows are  
retrieved according to specifications provided in a previously established and populated  
extended SQL descriptor area (XSQLDA) that describes the user’s request. The syntax for  
the DSQL FETCH statement is:  
FETCH cursorname USING DESCRIPTOR descriptorname;  

For example, the following C code fragment declares XSQLDA structures for input and  
output, and illustrates how the output structure is used in a FETCH statement:  

   XSQLDA *InputSqlda, *OutputSqlda;  
   . . .
EXEC SQL
   FETCH C USING DESCRIPTOR OutputSqlDa;
   . . .

For more information about creating and filling XSQLDA structures, and preparing DSQL queries with PREPARE, see Chapter 13, “Using Dynamic SQL.”

Joining tables

Joins enable retrieval of data from two or more tables in a database with a single SELECT. The tables from which data is to be extracted are listed in the FROM clause. Optional syntax in the FROM clause can reduce the number of rows returned, and additional WHERE clause syntax can further reduce the number of rows returned.

From the information in a SELECT that describes a join, InterBase builds a table that contains the results of the join operation, the results table, sometimes also called a dynamic or virtual table.

InterBase supports two types of joins:

- **Inner joins** link rows in tables based on specified join conditions, and return only those rows that match the join conditions. There are three types of inner joins:
  - **Equi-joins** link rows based on common values or equality relationships in the join columns.
  - J oins that link rows based on comparisons other than equality in the join columns. There is not an officially recognized name for these types of joins, but for simplicity’s sake they may be categorized as comparative joins, or non-equij oins.
  - Reflexive or self-joins, compare values within a column of a single table.

- **Outer joins** link rows in tables based on specified join conditions and return both rows that match the join conditions, and all other rows from one or more tables even if they do not match the join condition.

The most commonly used joins are inner joins, because they both restrict the data returned, and show a clear relationship between two or more tables. Outer joins, however, are useful for viewing joined rows against a background of rows that do not meet the join conditions.
Choosing join columns

How do you choose which columns to join? At a minimum, they must be of compatible datatypes and of similar content. You cannot, for example, join a CHAR column to an INTEGER column. A common and reliable criterion is to join the foreign key of one table to its referenced primary key. Often, joins are made between identical columns in two tables. For example, you might join the Job and Employee tables on their respective job_code columns.

INTEGER, DECIMAL, NUMERIC, and FLOAT datatypes can be compared to one another because they are all numbers. String values, like CHAR and VARCHAR, can only be compared to other string values unless they contain ASCII values that are all numbers. The CAST() function can be used to force translation of one InterBase datatype to another for comparisons. For more information about CAST(), see “Using CAST() for datatype conversions” on page 125.

IMPORTANT If a joined column contains a NULL value for a given row, InterBase does not include that row in the results table unless performing an outer join.

Using inner joins

InterBase supports two methods for creating inner joins. For portability and compatibility with existing SQL applications, InterBase continues to support the old SQL method for specifying joins. In older versions of SQL, there is no explicit join language. An inner join is specified by listing tables to join in the FROM clause of a SELECT, and the columns to compare in the WHERE clause.

For example, the following join returns the department name, manager number, and salary for any manager whose salary accounts for one third or more of the total salaries of employees in that department.

EXEC SQL
DECLARE BIG_SAL CURSOR FOR
SELECT D.DEPARTMENT, D.MNGR_NO, E.SALARY
FROM DEPARTMENT D, EMPLOYEE E
WHERE D.MNGR_NO = E.EMP_NO
AND E.SALARY*2 >= (SELECT SUM(S.SALARY) FROM EMPLOYEE S
WHERE D.DEPT_NO = S.DEPT_NO)
ORDER BY D.DEPARTMENT;

InterBase also implements new, explicit join syntax based on SQL-92:

SELECT col [, col ...] | *
JOINING TABLES

FROM <tablerefleft> [INNER] JOIN <tablerefright>
  [ON <searchcondition>]
  [WHERE <searchcondition>];

The join is explicitly declared in the FROM clause using the JOIN keyword. The table reference appearing to the left of the JOIN keyword is called the left table, while the table to the right of the JOIN is called the right table. The conditions of the join—the columns from each table—are stated in the ON clause. The WHERE clause contains search conditions that limit the number of rows returned. For example, using the new join syntax, the previously described query can be rewritten as:

EXEC SQL
DECLARE BIG_SAL CURSOR FOR
  SELECT D.DEPARTMENT, D.MNGR_NO, E.SALARY
  FROM DEPARTMENT D INNER JOIN EMPLOYEE E
    ON D.MNGR_NO = E.EMP_NO
    WHERE E.SALARY*2 > (SELECT SUM(S.SALARY) FROM EMPLOYEE S
      WHERE D.DEPT_NO = S.DEPT_NO)
  ORDER BY D.DEPARTMENT;

The new join syntax offers several advantages. An explicit join declaration makes the intention of the program clear when reading its source code.

The ON clause contains join conditions. The WHERE clause can contains conditions that restrict which rows are returned.

The FROM clause also permits the use of table references, which can be used to construct joins between three or more tables. For more information about nested joins, see “Using nested joins” on page 161.

Creating equi-joins

An inner join that matches values in join columns is called an equi-join. Equi-joins are among the most common join operations. The ON clause in an equi-join always takes the form:

ON t1.column = t2.column

For example, the following join returns a list of cities around the world if the capital cities also appear in the CITIES table, and also returns the populations of those cities:

EXEC SQL
DECLARE CAPPOP CURSOR FOR
  SELECT COU.NAME, COU.CAPITAL, CIT.POPULATION
  FROM COUNTRIES COU JOIN CITIES CIT ON CIT.NAME = COU.CAPITAL
    WHERE COU.CAPITAL NOT NULL
  ORDER BY COU.NAME;
In this example, the ON clause specifies that the CITIES table must contain a city name that matches a capital name in the COUNTRIES table if a row is to be returned. Note that the WHERE clause restricts rows retrieved from the COUNTRIES table to those where the CAPITAL column contains a value.

**Joins based on comparison operators**

Inner joins can compare values in join columns using other comparison operators besides the equality operator. For example, a join might be based on a column in one table having a value less than the value in a column in another table. The ON clause in a comparison join always takes the form:

```
ON t1.column <operator> t2.column
```

where `operator` is a valid comparison operator. For a list of valid comparison operators, see “Using comparison operators in expressions” on page 114.

For example, the following join returns information about provinces in Canada that are larger than the state of Alaska in the United States:

```
EXEC SQL
DECLARE BIGPROVINCE CURSOR FOR
  SELECT S.STATE_NAME, S.AREA, P.PROVINCE_NAME, P.AREA
  FROM STATES S JOIN PROVINCE P ON P.AREA > S.AREA AND
    P.COUNTRY = 'Canada'
  WHERE S.STATE_NAME = 'Alaska';
```

In this example, the first comparison operator in the ON clause tests to see if the area of a province is greater than the area of any state (the WHERE clause restricts final output to display only information for provinces that are larger in area than the state of Alaska).

**Creating self-joins**

A self-join is an inner join where a table is joined to itself to correlate columns of data. For example, the RIVERS table lists rivers by name, and, for each river, lists the river into which it flows. Not all rivers, of course, flow into other rivers. To discover which rivers flow into other rivers, and what their names are, the RIVERS table must be joined to itself:

```
EXEC SQL
DECLARE RIVERSTORIVERS CURSOR FOR
  SELECT R1.RIVER, R2.RIVER
  FROM RIVERS R1 JOIN RIVERS R2 ON R2.OUTFLOW = R1.RIVER
  ORDER BY R1.RIVER, R2.SOURCE;
```
As this example illustrates, when a table is joined to itself, each invocation of the table must be assigned a unique correlation name (R1 and R2 are correlation names in the example). For more information about assigning and using correlation names, see “Declaring and using correlation names” on page 134.

Using outer joins

Outer joins produce a results table that contains columns from every row in one table, and a subset of rows from another table. Actually, one type of outer join returns all rows from each table, but this type of join is used less frequently than other types. Outer join syntax is very similar to that of inner joins:

```
SELECT col [, col ...] | *
FROM <tablerefleft> {LEFT | RIGHT | FULL} [OUTER] JOIN
<tablerefright> [ON <searchcondition>]
[WHERE <searchcondition>];
```

Outer join syntax requires that you specify the type of join to perform. There are three possibilities:

- **A left outer join** retrieves all rows from the left table in a join, and retrieves any rows from the right table that match the search condition specified in the ON clause.

- **A right outer join** retrieves all rows from the right table in a join, and retrieves any rows from the left table that match the search condition specified in the ON clause.

- **A full outer join** retrieves all rows from both the left and right tables in a join regardless of the search condition specified in the ON clause.

Outer joins are useful for comparing a subset of data to the background of all data from which it is retrieved. For example, when listing those countries which contain the sources of rivers, it may be interesting to see those countries which are not the sources of rivers as well.

**Using a left outer join**

The left outer join is more commonly used than other types of outer joins. The following left outer join retrieves those countries that contain the sources of rivers, and identifies those countries that do not have NULL values in the R.RIVERS column:

```
EXEC SQL
  DECLARE RIVSOURCE CURSOR FOR
  SELECT C.COUNTRY, R.RIVER
  FROM COUNTRIES C LEFT JOIN RIVERS R ON R.SOURCE = C.COUNTRY
  ORDER BY C.COUNTRY;
```
The ON clause enables join search conditions to be expressed in the FROM clause. The search condition that follows the ON clause is the only place where retrieval of rows can be restricted based on columns appearing in the right table. The WHERE clause can be used to further restrict rows based solely on columns in the left (outer) table.

**Using a right outer join**

A right outer join retrieves all rows from the right table in a join, and only those rows from the left table that match the search condition specified in the ON clause. The following right outer join retrieves a list of rivers and their countries of origin, but also reports those countries that are not the source of any river:

```
EXEC SQL
DECLARE RIVSOURCE CURSOR FOR
SELECT R.RIVER, C.COUNTRY
FROM RIVERS.R RIGHT JOIN COUNTRIES C ON C.COUNTRY = R.SOURCE
ORDER BY C.COUNTRY;
```

**Tip** Most right outer joins can be rewritten as left outer joins by reversing the order in which tables are listed.

**Using a full outer join**

A full outer join returns all selected columns that do not contain NULL values from each table in the FROM clause without regard to search conditions. It is useful to consolidate similar data from disparate tables.

For example, several tables in a database may contain city names. Assuming triggers have not been created that ensure that a city entered in one table is also entered in the others to which it also applies, one of the only ways to see a list of all cities in the database is to use full outer joins. The following example uses two full outer joins to retrieve the name of every city listed in three tables, COUNTRIES, CITIES, and NATIONAL_PARKS:

```
EXEC SQL
DECLARE ALLCITIES CURSOR FOR
SELECT DISTINCT CIT.CITY, COU.CAPITAL, N.PARKCITY
FROM (CITIES CIT FULL JOIN COUNTRIES COU) FULL
JOIN NATIONAL_PARKS N;
```

This example uses a nested full outer join to process all rows from the CITIES and COUNTRIES tables. The result table produced by that operation is then used as the left table of the full outer join with the NATIONAL_PARKS table. For more information about using nested joins, see “Using nested joins” on page 161.
Note In most databases where tables share similar or related information, triggers are usually created to ensure that all tables are updated with shared information. For more information about triggers, see the Data Definition Guide.

Using nested joins

The SELECT statement FROM clause can be used to specify any combination of available tables or table references, parenthetical, nested joins whose results tables are created and then processed as if they were actual tables stored in the database. Table references are flexible and powerful, enabling the succinct creation of complex joins in a single location in a SELECT.

For example, the following statement contains a parenthetical outer join that creates a results table with the names of every city in the CITIES table even if the city is not associated with a country in the COUNTRIES table. The results table is then processed as the left table of an inner join that returns only those cities that have professional sports teams of any kind, the name of the team, and the sport the team plays.

```sql
DECLARE SPORTSCITIES CURSOR FOR
    SELECT COU.COUNTRY, C.CITY, T.TEAM, T.SPORT
    FROM (CITIES CIT LEFT JOIN COUNTRIES COU ON COU.COUNTRY = CIT.COUNTRY) INNER JOIN TEAMS T ON T.CITY = C.CITY
    ORDER BY COU.COUNTRY;
```

For more information about left joins, see “Using outer joins” on page 159.

Using subqueries

A subquery is a parenthetical SELECT statement nested inside the WHERE clause of another SELECT statement, where it functions as a search condition to restrict the number of rows returned by the outer, or parent, query. A subquery can refer to the same table or tables as its parent query, or to other tables.

The elementary syntax for a subquery is:

```sql
SELECT [DISTINCT] col [, col ...]
FROM <tableref> [, <tableref> ...]
WHERE {expression [[NOT] IN | comparison_operator]
| [NOT] EXISTS} (SELECT [DISTINCT] col [, col ...]
    FROM <tableref> [, <tableref> ...]
    WHERE <search_condition>);
```
Because a subquery is a search condition, it is usually evaluated before its parent query, which then uses the result to determine whether or not a row qualifies for retrieval. The only exception is the correlated subquery, where the parent query provides values for the subquery to evaluate. For more information about correlated subqueries, see “Correlated subqueries” on page 163.

A subquery determines the search condition for a parent’s WHERE clause in one of the following ways:

- Produces a list of values for evaluation by an IN operator in the parent query’s WHERE clause, or where a comparison operator is modified by the ALL, ANY, or SOME operators.
- Returns a single value for use with a comparison operator.
- Tests whether or not data meets conditions specified by an EXISTS operator in the parent query’s WHERE clause.

Subqueries can be nested within other subqueries as search conditions, establishing a chain of parent/child queries.

Simple subqueries

A subquery is especially useful for extracting data from a single table when a self-join is inadequate. For example, it is impossible to retrieve a list of those countries with a larger than average area by joining the COUNTRIES table to itself. A subquery, however, can easily return that information.

EXEC SQL
    DECLARE LARGECOUNTRIES CURSOR FOR
    SELECT COUNTRY, AREA
    FROM COUNTRIES
    WHERE AREA > (SELECT AVG(AREA) FROM COUNTRIES);
    ORDER BY AREA;

In this example, both the query and subquery refer to the same table. Queries and subqueries can refer to different tables, too. For example, the following query refers to the CITIES table, and includes a subquery that refers to the COUNTRIES table:

EXEC SQL
    DECLARE EUROCAPPOP CURSOR FOR
    SELECT CIT.CITY, CIT.POPULATION
    FROM CITIES CIT
    WHERE CIT.CITY IN (SELECT COU.CAPITAL FROM COUNTRIES COU
                          WHERE COU.CONTINENT = 'Europe')
    ORDER BY CIT.CITY;
This example uses correlation names to distinguish between tables even though the query and subquery reference separate tables. Correlation names are only necessary when both a query and subquery refer to the same tables and those tables share column names, but it is good programming practice to use them. For more information about using correlation names, see “Declaring and using correlation names” on page 134.

**Correlated subqueries**

A *correlated subquery* is a subquery that depends on its parent query for the values it evaluates. Because each row evaluated by the parent query is potentially different, the subquery is executed once for each row presented to it by the parent query.

For example, the following query lists each country for which there are three or more cities stored in the CITIES table. For each row in the COUNTRIES table, a country name is retrieved in the parent query, then used in the comparison operation in the subquery’s *WHERE* clause to verify if a city in the CITIES table should be counted by the `COUNT()` function. If `COUNT()` exceeds 2 for a row, the row is retrieved.

```sql
EXEC SQL
DECLARE TRICITIES CURSOR FOR
SELECT COUNTRY
FROM COUNTRIES COU
WHERE 3 <= (SELECT COUNT (*)
            FROM CITIES CIT
            WHERE CIT.CITY = COU.CAPITAL);
```

Simple and correlated subqueries can be nested and mixed to build complex queries. For example, the following query retrieves the country name, capital city, and largest city of countries whose areas are larger than the average area of countries that have at least one city within 30 meters of sea level:

```sql
EXEC SQL
DECLARE SEACOUNTRIES CURSOR FOR
SELECT CO1.COUNTRY, C01.CAPITAL, CI1.CITY
FROM COUNTRIES C01, CITIES CI1
WHERE CO1.COUNTRY = CI1.COUNTRY AND CI1.POPULATION =
    (SELECT MAX(CI2.POPULATION)
     FROM CITIES CI2 WHERE CI2.COUNTRY = CI1.COUNTRY)
    AND CO1.AREA >
    (SELECT AVG (CO2.AREA)
     FROM COUNTRIES CO2 WHERE EXISTS
```
When a table is separately searched by queries and subqueries, as in this example, each invocation of the table must establish a separate correlation name for the table. Using correlation names is the only method to assure that column references are associated with appropriate instances of their tables. For more information about correlation names, see "Declaring and using correlation names" on page 134.

Inserting data

New rows of data are added to one table at a time with the INSERT statement. To insert data, a user or stored procedure must have INSERT privilege for a table.

The INSERT statement enables data insertion from two different sources:
- A VALUES clause that contains a list of values to add, either through hard-coded values, or host-language variables.
- A SELECT statement that retrieves values from one table to add to another.

The syntax of INSERT is as follows:

```
INSERT [TRANSACTION name] INTO table [(col [, col ...])] 
  (VALUES (<val>[:ind] [, <val>[:ind] ...]) 
  | SELECT <clause>);
```

The list of columns into which to insert values is optional in DSQL applications. If it is omitted, then values are inserted into a table’s columns according to the order in which the columns were created. If there are more columns than values, the remaining columns are filled with zeros.

Using VALUES to insert columns

Use the VALUES clause to add a row of specific values to a table, or to add values entered by a user at run time. The list of values that follows the keyword can come from either from host-language variables, or from hard-coded assignments.

For example, the following statement adds a new row to the DEPARTMENT table using hard-coded value assignments:

```
EXEC SQL
```
INSERT INTO DEPARTMENT (DEPT_NO, DEPARTMENT)
VALUES (7734, 'Marketing');

Because the DEPARTMENT table contains additional columns not specified in the INSERT, NULL values are assigned to the missing fields.

The following C code example prompts a user for information to add to the DEPARTMENT table, and inserts those values from host variables:

```c
EXEC SQL
BEGIN DECLARE SECTION;
    char department[26], dept_no[16];
    int dept_num;
EXEC SQL
END DECLARE SECTION;

printf("Enter name of department: ");
gets(department);
printf("\nEnter department number: ");
depth_num = atoi(gets(dept_no));
EXEC SQL
    INSERT INTO COUNTRIES (DEPT_NO, DEPARTMENT)
    VALUES (:dept_num, :department);
```

When host variables are used in the values list, they must be preceded by colons (:), so that SQL can distinguish them from table column names.

---

**Using SELECT to insert columns**

To insert values from one table into another row in the same table or into a row in another table, use a SELECT statement to specify a list of insertion values. For example, the following INSERT statement copies DEPARTMENT and BUDGET information about the publications department from the OLDDDEPT table to the DEPARTMENT table. It also illustrates how values can be hard-coded into a SELECT statement to substitute actual column data.

```sql
EXEC SQL
    INSERT INTO DEPARTMENTS (DEPT_NO, DEPARTMENT, BUDGET)
    SELECT DEPT_NO, 'Publications', BUDGET
    FROM OLDDDEPT
    WHERE DEPARTMENT = 'Documentation';
```
The assignments in the SELECT can include arithmetic operations. For example, suppose an application keeps track of employees by using an employee number. When a new employee is hired, the following statement inserts a new employee row into the EMPLOYEE table, and assigns a new employee number to the row by using a SELECT statement to find the current maximum employee number and adding one to it. It also reads values for LAST_NAME and FIRST_NAME from the host variables, lastname, and firstname.

EXEC SQL
    INSERT INTO EMPLOYEE (EMP_NO, LAST_NAME, FIRST_NAME)
    SELECT (MAX(EMP_NO) + 1, :lastname, :firstname)
    FROM EMPLOYEE;

Inserting rows with NULL column values

Sometimes when a new row is added to a table, values are not necessary or available for all its columns. In these cases, a NULL value should be assigned to those columns when the row is inserted. There are three ways to assign a NULL value to a column on insertion:

- Ignore the column.
- Assign a NULL value to the column. This is standard SQL practice.
- Use indicator variables.

Ignoring a column

A NULL value is assigned to any column that is not explicitly specified in an INTO clause. When InterBase encounters an unreferenced column during insertion, it sets a flag for the column indicating that its value is unknown. For example, the DEPARTMENT table contains several columns, among them HEAD_DEPT, MGR_NO, and BUDGET. The following INSERT does not provide values for these columns:

EXEC SQL
    INSERT INTO DEPARTMENT (DEPT_NO, DEPARTMENT)
    VALUES (:newdept_no, :newdept_name);

Because HEAD_DEPT, MGR_NO, and BUDGET are not specified, InterBase sets the NULL value flag for each of these columns.

Note If a column is added to an existing table, InterBase sets a NULL value flag for all existing rows in the table.
Assigning a NULL value to a column

When a specific value is not provided for a column on insertion, it is standard SQL practice to assign a NULL value to that column. In InterBase a column is set to NULL by specifying NULL for the column in the INSERT statement.

For example, the following statement stores a row into the DEPARTMENT table, assigns the values of host variables to some columns, and assigns a NULL value to other columns:

```
EXEC SQL
    INSERT INTO DEPARTMENT
    (DEPT_NO, DEPARTMENT, HEAD_DEPT, MNGR_NO, BUDGET,
     LOCATION, PHONE_NO)
    VALUES (:dept_no, :dept_name, NULL, NULL, 1500000, NULL, NULL);
```

Using indicator variables

Another method for trapping and assigning NULL values—through indicator variables—is necessary in applications that prompt users for data, where users can choose not to enter values. By default, when InterBase stores new data, it stores zeroes for NULL numeric data, and spaces for NULL character data. Because zeroes and spaces may be valid data, it becomes impossible to distinguish missing data in the new row from actual zeroes and spaces.

To trap missing data with indicator variables, and store NULL value flags, follow these steps:

1. Declare a host-language variable to use as an indicator variable.
2. Test a value entered by the user and set the indicator variable to one of the following values:

   - 0 The host-language variable contains data.
   - -1 The host-language variable does not contain data.

3. Associate the indicator variable with the host variable in the INSERT statement using the following syntax:

   ```sql
   INSERT INTO table (<col> [, <col> ...])
   VALUES (:variable [INDICATOR] :indicator
                  [, :variable [INDICATOR] :indicator ...]);
   ```

   **Note** The INDICATOR keyword is optional.
For example, the following C code fragment prompts the user for the name of a department, the department number, and a budget for the department. It tests that the user has entered a budget. If not, it sets the indicator variable, \textit{bi}, to \(-1\). Otherwise, it sets \textit{bi} to 0. Finally, the program \texttt{INSERTS} the information into the \texttt{DEPARTMENT} table. If the indicator variable is \(-1\), then no actual data is stored in the \texttt{BUDGET} column, but a flag is set for the column indicating that the value is \texttt{NULL}.

\begin{verbatim}
EXEC SQL
   BEGIN DECLARE SECTION;
   short bi; /* indicator variable declaration */
   char department[26], dept_no_ascii[26], budget_ascii[26];
   long num_val; /* host variable for inserting budget */
   short dept_no;
EXEC SQL
   END DECLARE SECTION;

. . .
printf("Enter new department name: ");
gets(cidepartment);
printf("\nEnter department number: ");
gets(dept_no_ascii);
printf("\nEnter department’s budget: ");
gets(budget_ascii);
if (budget_ascii = "")
{
   bi = -1; num_val = 0;
}
else
{
   bi = 0;
   num_val = atoi(budget_ascii);
}
depth_no = atoi(dept_no_ascii);
EXEC SQL
   INSERT INTO DEPARTMENT (DEPARTMENT, DEPT_NO, BUDGET)
   VALUES (:department, :dept_no, :num_val INDICATOR :bi);
. . .
\end{verbatim}

Indicator status can also be determined for data retrieved from a table. For information about trapping \texttt{NULL} values retrieved from a table, see \textbf{“Retrieving indicator status” on page 148.}
Inserting data through a view

New rows can be inserted through a view if the following conditions are met:

- The view is updatable. For a complete discussion of updatable views, see the Data Definition Guide.
- The view is created using the WITH CHECK OPTION.
- A user or stored procedure has INSERT privilege for the view.

Values can only be inserted through a view for those columns named in the view. InterBase stores NULL values for unreferenced columns. For example, suppose the view, PART_DEPT, is defined as follows:

```sql
CREATE VIEW PART_DEPT
(DEPARTMENT, DEPT_NO, BUDGET)
AS SELECT DEPARTMENT, DEPT_NO, BUDGET
FROM DEPARTMENT
WHERE DEPT_NO NOT NULL AND BUDGET > 50000
WITH CHECK OPTION;
```

Because PART_DEPT references a single table, DEPARTMENT, new data can be inserted for the DEPARTMENT, DEPT_NO, and BUDGET columns. The WITH CHECK OPTION assures that all values entered through the view fall within ranges of values that can be selected by this view. For example, the following statement inserts a new row for the Publications department through the PART_DEPT view:

```sql
INSERT INTO PART_DEPT (DEPARTMENT, DEPT_NO, BUDGET)
VALUES ('Publications', '7735', 1500000);
```

InterBase inserts NULL values for all other columns in the DEPARTMENT table that are not available directly through the view.

For information about creating a view, see Chapter 5, “Working with Data Definition Statements.” For the complete syntax of CREATE VIEW, see the Language Reference.

Note See the chapter on triggers in the Data Definition Guide for tips on using triggers to update non-updatable views.

Specifying transaction names in an INSERT

InterBase enables an SQL application to run simultaneous transactions if:
Each transaction is first named with a SET TRANSACTION statement. For a complete discussion of transaction handling and naming, see Chapter 4, "Working with Transactions."

Each data manipulation statement (SELECT, INSERT, UPDATE, DELETE, DECLARE, OPEN, FETCH, and CLOSE) specifies a TRANSACTION clause that identifies the name of the transaction under which it operates.

SQL statements are not dynamic (DSQL). DSQL does not support user-specified transaction names.

With INSERT, the TRANSACTION clause intervenes between the INSERT keyword and the list of columns to insert, as in the following syntax fragment:

```sql
INSERT TRANSACTION name INTO table (col [, col ...])
```

The TRANSACTION clause is optional in single-transaction programs. It must be used in a multi-transaction program unless a statement operates under control of the default transaction, GDS__TRANS. For example, the following INSERT is controlled by the transaction, T1:

```sql
EXEC SQL
    INSERT TRANSACTION T1 INTO DEPARTMENT (DEPARTMENT, DEPT_NO, BUDGET)
    VALUES (:deptname, :deptno, :budget INDICATOR :bi);
```

### Updating data

To change values for existing rows of data in a table, use the UPDATE statement. To update a table, a user or procedure must have UPDATE privilege for it. The syntax of UPDATE is:

```sql
UPDATE [TRANSACTION name] table
    SET col = <assignment> [, col = <assignment> ...]
    WHERE <search_condition> | WHERE CURRENT OF cursorname;
```

UPDATE changes values for columns specified in the SET clause; columns not listed in the SET clause are not changed. A single UPDATE statement can be used to modify any number of rows in a table. For example, the following statement modifies a single row:

```sql
EXEC SQL
    UPDATE DEPARTMENT
    SET DEPARTMENT = 'Publications'
    WHERE DEPARTMENT = 'Documentation';
```
The WHERE clause in this example targets a single row for update. If the same change should be propagated to a number of rows in a table, the WHERE clause can be more general. For example, to change all occurrences of "Documentation" to "Publications" for all departments in the DEPARTMENT table where DEPARTMENT equals "Documentation," the UPDATE statement would be as follows:

```
EXEC SQL
  UPDATE DEPARTMENT
    SET DEPARTMENT = 'Publications'
    WHERE DEPARTMENT = 'Documentation';
```

Using UPDATE to make the same modification to a number of rows is sometimes called a mass update, or a searched update.

The WHERE clause in an UPDATE statement can contain a subquery that references one or more other tables. For a complete discussion of subqueries, see “Using subqueries” on page 161.

### Updating multiple rows

There are two basic methods for modifying rows:

- The searched update method, where the same changes are applied to a number of rows, is most useful for automated updating of rows without a cursor.
- The positioned update method, where rows are retrieved through a cursor and updated row by row, is most useful for enabling users to enter different changes for each row retrieved.

A searched update is easier to program than a positioned update, but also more limited in what it can accomplish.

#### Using a searched update

Use a searched update to make the same changes to a number of rows. The UPDATE SET clause specifies the actual changes that are to be made to columns for each row that matches the search condition specified in the WHERE clause. Values to set can be specified as constants or variables.

For example, the following C code fragment prompts for a country name and a percentage change in population, then updates all cities in that country with the new population:

```
... EXEC SQL
    BEGIN DECLARE SECTION;
```
CHARACTER country[26], asciimult[10];
int multiplier;
EXEC SQL
END DECLARE SECTION;
...
main ()
{
printf("Enter country with city populations needing adjustment: ");
gets(country);
printf("\nPercent change (100% to -100%: ");
gets(asciimult);
multiplier = atoi(asciimult);
EXEC SQL
UPDATE CITIES
   SET POPULATION = POPULATION * (1 + :multiplier / 100)
   WHERE COUNTRY = :country;
if (SQLCODE && (SQLCODE != 100))
{
   isc_print_sqlerr(SQLCODE, isc_status);
   EXEC SQL
      ROLLBACK RELEASE;
}
else
{ EXEC SQL
    COMMIT RELEASE;
}
}

IMPORTANT Searched updates cannot be performed on arrays of datatypes.

wagon a positioned update
Use cursors to select rows for update when prompting users for changes on a row-by-row basis, and displaying pre- or post-modification values between row updates. Updating through a cursor is a seven-step process:
1. Declare host-language variables needed for the update operation.
2. Declare a cursor describing the rows to retrieve for update, and include the FOR UPDATE clause in DSQL. For more information about declaring and using cursors, see “Selecting multiple rows” on page 144.
3. Open the cursor.
4. Fetch a row.
5. Display current values and prompt for new values.
6. Update the currently selected row using the WHERE CURRENT OF clause.
7. Repeat steps 3 to 7 until all selected rows are updated.

For example, the following C code fragment updates the POPULATION column by user-specified amounts for cities in the CITIES table that are in a country also specified by the user:

```c
EXEC SQL
BEGIN DECLARE SECTION;
    char country[26], asciimult[10];
    int multiplier;
EXEC SQL
END DECLARE SECTION;

main ()
{
EXEC SQL
    DECLARE CHANGEPOP CURSOR FOR
    SELECT CITY, POPULATION
    FROM CITIES
    WHERE COUNTRY = :country;

printf("Enter country with city populations needing adjustment: ");
gets(country);

EXEC SQL
    OPEN CHANGEPOP;
EXEC SQL
    FETCH CHANGEPOP INTO :country;
while(!SQLCODE)
{
    printf("\nPercent change (100% to -100%): ");
    gets(asciimult);
    multiplier = atoi(asciimult);
EXEC SQL
    UPDATE CITIES
    SET POPULATION = POPULATION * (1 + :multiplier / 100)
    WHERE CURRENT OF CHANGEPOP;
}
```
**EXEC SQL**

```sql
FETCH CHANGEPop INTO :country;
if (SQLCODE && (SQLCODE != 100))
{
    isc_print_sqlerr(SQLCODE, isc_status);
    EXEC SQL
    ROLLBACK RELEASE;
    exit(1);
}
EXEC SQL
    COMMIT RELEASE;
```

**IMPORTANT** Using FOR UPDATE with a cursor causes rows to be fetched from the database one at a time. If FOR UPDATE is omitted, rows are fetched in batches.

---

**NULLing columns with UPDATE**

To set a column’s value to NULL during update, specify a NULL value for the column in the **SET** clause. For example, the following **UPDATE** sets the budget of all departments without managers to NULL:

```sql
EXEC SQL
    UPDATE DEPARTMENT
    SET BUDGET = NULL
    WHERE MNGR_NO = NULL;
```

---

**Updating through a view**

Existing rows can be updated through a view if the following conditions are met:

- The view is updatable. For a complete discussion of updatable views, see the *Data Definition Guide*.
- The view is created using the **WITH CHECK OPTION**.
- A user or stored procedure has **UPDATE** privilege for the view.

Values can only be updated through a view for those columns named in the view. For example, suppose the view, **PART_DEPT**, is defined as follows:

```sql
EXEC SQL
CREATE VIEW PART_DEPT
(DEPARTMENT, NUMBER, BUDGET)
AS SELECT DEPARTMENT, DEPT_NO, BUDGET
FROM DEPARTMENT
WITH CHECK OPTION;

Because PART_DEPT references a single table, data can be updated for the columns named
in the view. The WITH CHECK OPTION assures that all values entered through the view fall
within ranges prescribed for each column when the DEPARTMENT table was created. For
example, the following statement updates the budget of the Publications department
through the PART_DEPT view:

EXEC SQL
UPDATE PART_DEPT
  SET BUDGET = 2505700
WHERE DEPARTMENT = 'Publications';

For information about creating a view, see Chapter 5, "Working with Data Definition
Statements." For the complete syntax of CREATE VIEW, see the Language Reference.

Note See the chapter on triggers in the Data Definition Guide for tips on using triggers
to update non-updatable views.

---

**Specifying transaction names in UPDATE**

InterBase enables an SQL application to run simultaneous transactions if:

- Each transaction is first named with a SET TRANSACTION statement. For a complete
discussion of transaction handling and naming, see Chapter 4, "Working with
Transactions."

- Each data manipulation statement (SELECT, INSERT, UPDATE, DELETE, DECLARE, OPEN,
FETCH, and CLOSE) specifies a TRANSACTION clause that identifies the name of the
transaction under which it operates.

- SQL statements are not dynamic (DSQL). DSQL does not support multiple simultaneous
transactions.

In UPDATE, the TRANSACTION clause intervenes between the UPDATE keyword and the
name of the table to update, as in the following syntax:

```
UPDATE [TRANSACTION name] table
  SET col = <assignment> [, col = <assignment> ...]
WHERE <search_condition> | WHERE CURRENT OF cursorname;
```
The TRANSACTION clause must be used in multi-transaction programs, but is optional in single-transaction programs or in programs where only one transaction is open at a time. For example, the following UPDATE is controlled by the transaction, T1:

EXEC SQL
  UPDATE TRANSACTION T1 DEPARTMENT
  SET BUDGET = 2505700
  WHERE DEPARTMENT = 'Publications';

Deleting data

To remove rows of data from a table, use the DELETE statement. To delete rows a user or procedure must have DELETE privilege for the table.

The syntax of DELETE is:

DELETE [TRANSACTION name] FROM table
  WHERE <search_condition> | WHERE CURRENT OF cursorname;

DELETE irretrievably removes entire rows from the table specified in the FROM clause, regardless of each column’s datatype.

A single DELETE can be used to remove any number of rows in a table. For example, the following statement removes the single row containing “Channel Marketing” from the DEPARTMENT table:

EXEC SQL
  DELETE FROM DEPARTMENT
  WHERE DEPARTMENT = 'Channel Marketing';

The WHERE clause in this example targets a single row for update. If the same deletion criteria apply to a number of rows in a table, the WHERE clause can be more general. For example, to remove all rows from the DEPARTMENT table with BUDGET values < $1,000,000, the DELETE statement would be as follows:

EXEC SQL
  DELETE FROM DEPARTMENT
  WHERE BUDGET < 1000000;

Using DELETE to remove a number of rows is sometimes called a mass delete.

The WHERE clause in a DELETE statement can contain a subquery that references one or more other tables. For a discussion of subqueries, see “Using subqueries” on page 161.
Deleting multiple rows

There are two methods for modifying rows:

- The *searched delete* method, where the same deletion condition applies to a number of rows, is most useful for automated removal of rows.

- The *positioned delete* method, where rows are retrieved through a cursor and deleted row by row, is most useful for enabling users to choose which rows that meet certain conditions should be removed.

A searched delete is easier to program than a positioned delete, but less flexible.

*Using a searched delete*

Use a searched delete to remove a number of rows that match a condition specified in the WHERE clause. For example, the following C code fragment prompts for a country name, then deletes all rows that have cities in that country:

```c
EXEC SQL
BEGIN DECLARE SECTION;
  char country[26];
EXEC SQL
END DECLARE SECTION;

main ()
{
  printf("Enter country with cities to delete: ");
  gets(country);
  EXEC SQL
    DELETE FROM CITIES
    WHERE COUNTRY = :country;

  if(SQLCODE && (SQLCODE != 100))
  {
    isc_print_sqlerr(SQLCODE, isc_status);
    EXEC SQL
      ROLLBACK RELEASE;
  }
  else
  {
    EXEC SQL
      COMMIT RELEASE;
  }
```
Using a positioned delete

Use cursors to select rows for deletion when users should decide deletion on a row-by-row basis, and displaying pre- or post-modification values between row updates. Updating through a cursor is a seven-step process:

1. Declare host-language variables needed for the delete operation.

2. Declare a cursor describing the rows to retrieve for possible deletion, and include the FOR UPDATE clause. For more information about declaring and using cursors, see “Selecting multiple rows” on page 144.

3. Open the cursor.

4. Fetch a row.

5. Display current values and prompt for permission to delete.

6. Delete the currently selected row using the WHERE CURRENT OF clause to specify the name of the cursor.

7. Repeat steps 3 to 7 until all selected rows are deleted.

For example, the following C code deletes rows in the CITIES table that are in North America only if a user types Y when prompted:

```c
. . .
EXEC SQL
BEGIN DECLARE SECTION;
  char cityname[26];
EXEC SQL
END DECLARE SECTION;
char response[5];
. . .
main ()
{
  EXEC SQL
  DECLARE DELETECITY CURSOR FOR
    SELECT CITY,
    FROM CITIES
    WHERE CONTINENT = 'North America';
EXEC SQL
  OPEN DELETECITY;
  while (!SQLCODE)
  {
```
EXEC SQL
  FETCH DELETECITY INTO :cityname;
if (SQLCODE)
{
  if (SQLCODE == 100)
  {
    printf('Deletions complete.');
    EXEC SQL
      COMMIT;
    EXEC SQL
      CLOSE DELETECITY;
    EXEC SQL
      DISCONNECT ALL;
  }
  isc_print_sqlerr(SQLCODE, isc_status);
  EXEC SQL
    ROLLBACK;
  EXEC SQL
    DISCONNECT ALL;
  exit(1);
}
printf("\nDelete %s (Y/N)?", cityname);
gets(response);
if(response[0] == 'Y' || response == 'y')
{
  EXEC SQL
    DELETE FROM CITIES
    WHERE CURRENT OF DELETECITY;
  if(SQLCODE && (SQLCODE != 100))
  {
    isc_print_sqlerr(SQLCODE, isc_status);
    EXEC SQL
      ROLLBACK;
    EXEC SQL
      DISCONNECT;
    exit(1);
  }
}
Deleting through a view

You can delete entire rows through a view if the following conditions are met:

- The view is updatable. For a complete discussion of updatable views, see the *Data Definition Guide*.
- A user or stored procedure has DELETE privilege for the view.

For example, the following statement deletes all departments with budgets under $1,000,000, from the DEPARTMENT table through the PART_DEPT view:

```sql
EXEC SQL
  DELETE FROM PART_DEPT
  WHERE BUDGET < 1000000;
```

For information about creating a view, see *Chapter 5, “Working with Data Definition Statements.”* For CREATE VIEW syntax, see the *Language Reference*.

**Note** See the chapter on triggers in the *Data Definition Guide* for tips on using triggers to delete through non-updatable views.

---

Specifying transaction names in a DELETE

InterBase enables an SQL application to run simultaneous transactions if:

- Each transaction is first named with a SET TRANSACTION statement. For a complete discussion of transaction handling and naming, see *Chapter 4, “Working with Transactions.”*
- Each data manipulation statement (SELECT, INSERT, UPDATE, DELETE, DECLARE, OPEN, FETCH, and CLOSE) specifies a TRANSACTION clause that identifies the name of the transaction under which it operates.
- SQL statements are not dynamic (DSQL). DSQL does not support multiple simultaneous transactions.

For DELETE, the TRANSACTION clause intervenes between the DELETE keyword and the FROM clause specifying the table from which to delete:

```
DELETE TRANSACTION name FROM table ...```
The TRANSACTION clause is optional in single-transaction programs or in programs where only one transaction is open at a time. It must be used in a multi-transaction program. For example, the following DELETE is controlled by the transaction, T1:

EXEC SQL
DELETE TRANSACTION T1 FROM PART_DEPT
WHERE BUDGET < 1000000;
Most host languages do not support the DATE, TIME, and TIMESTAMP datatypes. Instead, they treat dates as strings or structures. InterBase supports DATE and TIME datatypes that are stored as a single long integers, and a TIMESTAMP datatype that is stored in tables as two long integers. An InterBase DATE datatype includes information about year, month, and day of the month, the TIME datatype includes information about time, and the TIMESTAMP datatype is a combination of the two.

This chapter discusses how to SELECT, INSERT, and UPDATE dates from tables in SQL applications using the following isc call interface routines:

- `isc_decode_sql_date()` converts the InterBase internal date format to the C time structure
- `isc_encode_sql_date()` converts the C time structure to the internal InterBase date format
- `isc_decode_sql_time()` converts the InterBase internal time format to the C time structure
- `sql_encode_sql_time()` converts the C time structure to the internal InterBase time format
- `isc_decode_timestamp()` converts the InterBase internal timestamp format to the C time structure; this was formerly `isc_decode_date()`
- `isc_encode_timestamp()` converts the C time structure to the InterBase internal timestamp format; this was formerly `isc_encode_date()`

See the API Guide for a description of each of these functions.
The chapter also discusses how to use the CAST() function to translate DATE, TIME, and TIMESTAMP datatypes into each other or into CHAR datatypes and back again, and how to use the DATE literals, NOW and TODAY when selecting and inserting dates.

Selecting dates and times

To select a date and time (timestamp) from a table, and convert it to a form usable in a C language program, follow these steps:

1. Create a host variable for a C time structure. Most C and C++ compilers provide a typedef declaration, \texttt{struct tm}, for the C time structure in the \texttt{time.h} header file. The following C code includes that header file, and declares a variable of type \texttt{struct tm}:

   
   ```
   #include <time.h>
   ...
   struct tm hire_time;
   ...
   ```

   To create host-language time structures in languages other than C and C++, see the host-language reference manual.

2. Create a host variable of type \texttt{ISC_TIMESTAMP}. For example, the host-variable declaration might look like this:

   ```
   ISC_TIMESTAMP hire_date;
   ```

   The \texttt{ISC_TIMESTAMP} structure is automatically declared for programs when they are preprocessed with \texttt{gpre}, but the programmer must declare actual host-language variables of type \texttt{ISC_TIMESTAMP}.

3. Retrieve a timestamp from a table into the \texttt{ISC_TIMESTAMP} variable. For example,

   ```
   EXEC SQL
   SELECT LAST_NAME, FIRST_NAME, DATE_OF_HIRE
   INTO :lname, :fname, :hire_date
   FROM EMPLOYEE
   WHERE LAST_NAME = 'Smith' AND FIRST_NAME = 'Margaret';
   ```
Convert the \texttt{isc\_timestamp} variable into a numeric Unix format with the InterBase function, \texttt{isc\_decode\_timestamp()}. This function is automatically declared for programs when they are preprocessed with \texttt{gpre}. \texttt{isc\_decode\_timestamp()} requires two parameters: the address of the \texttt{isc\_timestamp} host-language variable, and the address of the \texttt{struct tm} host-language variable. For example, the following code fragment converts \textit{hire\_date} to \textit{hire\_time}:

\begin{verbatim}
isc_decode_timestamp(&hire_date, &hire_time);
\end{verbatim}

\section*{Inserting dates and times}

To insert a date and time (timestamp) in a table, it must be converted from the host-language format into InterBase format, and then stored. To perform the conversion and insertion in a C program, follow these steps:

1. Create a host variable for a C time structure. Most C and C++ compilers provide a typedef declaration, \texttt{struct tm}, for the C time structure in the \texttt{time.h} header file. The following C code includes that header file, and declares a \texttt{struct tm} variable, \textit{hire\_time}:

\begin{verbatim}
#include <time.h>
.
.
struct tm hire_time;
.
.
\end{verbatim}

To create host-language time structures in languages other than C and C++, see the host-language reference manual.

2. Create a host variable of type \texttt{ISC\_TIMESTAMP}, for use by InterBase. For example, the host-variable declaration might look like this:

\begin{verbatim}
ISC\_TIMESTAMP mydate;
\end{verbatim}

The \texttt{ISC\_TIMESTAMP} structure is automatically declared for programs when they are preprocessed with \texttt{gpre}, but the programmer must declare actual host-language variables of type \texttt{ISC\_TIMESTAMP}.

3. Put date information into \textit{hire\_time}.
4. Use the InterBase `isc_encode_timestamp()` function to convert the information in `hire_time` into InterBase internal format and store that formatted information in the `ISC_TIMESTAMP` host variable (`hire_date` in the example). This function is automatically declared for programs when they are preprocessed with `gpre`. `isc_encode_timestamp()` requires two parameters, the address of the Unix time structure, and the address of the `ISC_TIMESTAMP` host-language variable.

For example, the following code converts `hire_time` to `hire_date`:

```
isc_encode_timestamp(&hire_time, &hire_date);
```

5. Insert the date into a table. For example,

```
EXEC SQL
    INSERT INTO EMPLOYEE (EMP_NO, DEPARTMENT, DATE_OF_HIRE)
    VALUES (:emp_no, :deptname, :hire_date);
```

---

**Updating dates and times**

To update a DATE, TIME, or TIMESTAMP datatype in a table, you must convert it from the host-language format into InterBase format, and then store it. To convert a host variable into InterBase format, see “Inserting dates and times” on page 185. The actual update is performed using an UPDATE statement. For example,

```
EXEC SQL
    UPDATE EMPLOYEE
    SET DATE_OF_HIRE = :hire_date
    WHERE DATE_OF_HIRE < '1 JAN 1994'
```

---

**Using CAST() to convert dates and times**

The built-in `CAST()` function can be used in SELECT statements to translate between the following types:

- DATE, TIME, or TIMESTAMP datatype into a CHAR datatype
- CHAR datatype into a DATE, TIME, or TIMESTAMP datatype
- DATE or TIME datatype into a TIMESTAMP datatype
- TIMESTAMP datatype into a DATE or TIME datatype
Typically, `CAST()` is used in the `WHERE` clause to compare different datatypes. The syntax for `CAST()` is:

```
CAST (<value> AS <datatype>)
```

In the following `WHERE` clause, `CAST()` translates a `CHAR` datatype, `INTERVIEW_DATE`, to a `DATE` datatype to compare against a `DATE` datatype, `HIRE_DATE`:

```sql
... WHERE HIRE_DATE = CAST(INTERVIEW_DATE AS DATE);
```

In the next example, `CAST()` translates a `DATE` datatype into a `CHAR` datatype:

```sql
... WHERE CAST(HIRE_DATE AS CHAR) = INTERVIEW_DATE;
```

`CAST()` also can be used to compare columns with different datatypes in the same table, or across tables.

The following two sections show the possible conversions to and from datetime (`DATE`, `TIME`, and `TIMESTAMP`) datatypes and other SQL datatypes.

For more information about `CAST()`, see Chapter 6, “Working with Data.”

---

### Casting from SQL datatypes to datetime datatypes

The following table shows the SQL datatypes from which the `DATE`, `TIME`, and `TIMESTAMP` datatypes can be cast.

<table>
<thead>
<tr>
<th>CAST datatype below</th>
<th>TO datatype at right</th>
<th>TIMESTAMP</th>
<th>DATE</th>
<th>TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMALLINT</td>
<td>Error</td>
<td>Error</td>
<td>Error</td>
<td></td>
</tr>
<tr>
<td>INTEGER</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLOAT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DOUBLE PRECISION</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NUMERIC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DECIMAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VARCHAR(n)</td>
<td>Succeeds if the string is in the following format: YYYY-MM-DD</td>
<td>Succeeds if the string is in the following format: YYYY-MM-DD</td>
<td>Succeeds if the string is in the following format: HH:MM:SS.t thou</td>
<td></td>
</tr>
<tr>
<td>CHAR(n)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CSTRING(n)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BLOB</td>
<td>Error</td>
<td>Error</td>
<td>Error</td>
<td></td>
</tr>
</tbody>
</table>
Casting from datetime datatypes to other SQL datatypes

The following table shows the SQL datatypes into which the DATE, TIME, and TIMESTAMP datatypes can be cast.

<table>
<thead>
<tr>
<th>CAST datatype below</th>
<th>TIMESTAMP</th>
<th>DATE</th>
<th>TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIMESTAMP</td>
<td>Always succeeds</td>
<td>Succeeds: date portion of TIMESTAMP</td>
<td>Succeeds: time portion of TIMESTAMP</td>
</tr>
<tr>
<td>DATE</td>
<td>Succeeds: time portion of TIMESTAMP set to 0:0:0.0000</td>
<td>Always succeeds</td>
<td>Error</td>
</tr>
<tr>
<td>TIME</td>
<td>Succeeds: date portion of TIMESTAMP set to the base-0 date (17 November, 1858)</td>
<td>Error</td>
<td>Always succeeds</td>
</tr>
</tbody>
</table>

TABLE 7.1 Casting from SQL datatypes to datetime datatypes

Casting from datetime datatypes to other SQL datatypes

The following table shows the SQL datatypes into which the DATE, TIME, and TIMESTAMP datatypes can be cast.

<table>
<thead>
<tr>
<th>CAST datatype at right TO datatype below</th>
<th>TIMESTAMP</th>
<th>DATE</th>
<th>TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMALLINT</td>
<td>Error</td>
<td>Error</td>
<td>Error</td>
</tr>
<tr>
<td>INTEGER</td>
<td>Error</td>
<td>Error</td>
<td>Error</td>
</tr>
<tr>
<td>FLOAT</td>
<td>Error</td>
<td>Error</td>
<td>Error</td>
</tr>
<tr>
<td>DOUBLE PRECISION</td>
<td>Error</td>
<td>Error</td>
<td>Error</td>
</tr>
<tr>
<td>NUMERIC</td>
<td>Error</td>
<td>Error</td>
<td>Error</td>
</tr>
<tr>
<td>DECIMAL</td>
<td>Error</td>
<td>Error</td>
<td>Error</td>
</tr>
<tr>
<td>VARCHAR(n)</td>
<td>Succeeds if n is 24 characters or more; resulting string is in format: YYYY-MM-DD HH:MM:SS.thou</td>
<td>Succeeds if n is 10 characters or more; resulting string is in format: YYYY-MM-DD</td>
<td>Succeeds if n is 10 characters or more; resulting string is in format: HH:MM:SS.thou</td>
</tr>
<tr>
<td>CHAR(n)</td>
<td>Error</td>
<td>Error</td>
<td>Error</td>
</tr>
<tr>
<td>CSTRING(n)</td>
<td>Error</td>
<td>Error</td>
<td>Error</td>
</tr>
<tr>
<td>BLOB</td>
<td>Error</td>
<td>Error</td>
<td>Error</td>
</tr>
</tbody>
</table>

TABLE 7.2 Casting from datetime datatypes to other SQL datatypes
**Using date literals**

InterBase supports five date literals, 'TIMESTAMP', 'DATE', 'TIME', 'YESTERDAY', and 'TOMORROW'. *Date literals* are string values entered between quotation marks that can be interpreted as date values for EXTRACT, SELECT, INSERT, and UPDATE operations. 'TIMESTAMP' is a date literal that combines today’s date and time in InterBase format. 'DATE' is today’s date with time information set to zero. Similarly, 'YESTERDAY' and 'TOMORROW' are the expected dates with the time information set to zero.

In EXTRACT and SELECT, 'TIMESTAMP' and 'DATE' can be used in the search condition of a WHERE clause to restrict the data retrieved:

```sql
EXEC SQL
   SELECT * FROM CROSS_RATE WHERE UPDATE_DATE = 'DATE';
```

In INSERT and UPDATE, 'TIMESTAMP' and 'DATE' can be used to enter date and time values instead of relying on `isc` calls to convert C dates to InterBase dates:

```sql
EXEC SQL
   INSERT INTO CROSS_RATE VALUES(:from, :to, :rate, 'NOW');
EXEC SQL
   UPDATE CROSS_RATE
   SET CONV_RATE = 1.75,
   SET UPDATE_DATE = 'TIMESTAMP'
   WHERE FROM_CURRENCY = 'POUND' AND TO_CURRENCY = 'DOLLAR'
   AND UPDATE_DATE < 'TODAY';
```
This chapter describes the BLOB datatype and its subtypes, how to store Blobs, how to access them with SQL, DSQL, and API calls, and how to filter Blobs. It also includes information on writing Blob filters.

What is a Blob?

A Blob is a dynamically sizable datatype that has no specified size and encoding. You can use a Blob to store large amounts of data of various types, including:

- Bitmapped images
- Vector drawings
- Sounds, video segments, and other multimedia information
- Text and data, including book-length documents

Data stored in the Blob datatype can be manipulated in most of the same ways as data stored in any other datatype. InterBase stores Blob data inside the database, in contrast to similar other systems that store pointers to non-database files. For each Blob, there is a unique identification handle in the appropriate table to point to the database location of the Blob. By maintaining the Blob data within the database, InterBase improves data management and access.
The combination of true database management of Blob data and support for a variety of datatypes makes InterBase Blob support ideal for transaction-intensive multimedia applications. For example, InterBase is an excellent platform for interactive kiosk applications that might provide hundreds or thousands of product descriptions, photographs, and video clips, in addition to point-of-sale and order processing capabilities.

**How are Blob data stored?**

Blob is the InterBase datatype that represents various objects, such as bitmapped images, sound, video, and text. Before you store these items in the database, you create or manage them as platform- or product-specific files or data structures, such as:

- TIFF, PICT, BMP, WMF, GEM, TARGA or other bitmapped or vector-graphic files.
- MIDI or WAV sound files.
- Audio Video Interleaved format (.AVI) or QuickTime video files.
- ASCII, MIF, DOC, RTF, WPX or other text files.
- CAD files.

You must load these files from memory into the database programatically, as you do any other host-language data items or records you intend to store in InterBase.
### Blob subtypes

Although you manage Blob data in the same way as other datatypes, InterBase provides more flexible datatyping rules for Blob data. Because there are many native datatypes that you can define as Blob data, InterBase treats them somewhat generically and allows you to define your own datatype, known as a *subtype*. Also, InterBase provides seven standard subtypes with which you can characterize Blob data:

<table>
<thead>
<tr>
<th>Blob subtype</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Unstructured, generally applied to binary data or data of an indeterminate type</td>
</tr>
<tr>
<td>1</td>
<td>Text</td>
</tr>
<tr>
<td>2</td>
<td>Binary language representation (BLR)</td>
</tr>
<tr>
<td>3</td>
<td>Access control list</td>
</tr>
<tr>
<td>4</td>
<td>(Reserved for future use)</td>
</tr>
<tr>
<td>5</td>
<td>Encoded description of a table’s current metadata</td>
</tr>
<tr>
<td>6</td>
<td>Description of multi-database transaction that finished irregularly</td>
</tr>
</tbody>
</table>

**TABLE 8.1** Blob subtypes defined by InterBase

You can specify user-defined subtypes as negative numbers between −1 and −32,678. Positive integers are reserved for InterBase subtypes.

For example, the following statement defines three Blob columns: Blob1 with subtype 0 (the default), Blob2 with subtype 1 (TEXT), and Blob3 with user-defined subtype −1:

```sql
EXEC SQL CREATE TABLE TABLE2
{
  BLOB1 BLOB,
  BLOB2 BLOB SUB_TYPE 1,
  BLOB3 BLOB SUB_TYPE -1
};
```

To specify both a default segment length and a subtype when creating a Blob column, use the `SEGMENT SIZE` option after the `SUB_TYPE` option. For example:

```sql
EXEC SQL CREATE TABLE TABLE2
{
  BLOB1 BLOB SUB_TYPE 1 SEGMENT SIZE 100;
};
```
The only rule InterBase enforces over these user-defined subtypes is that, when converting a Blob from one subtype to another, those subtypes must be compatible. InterBase does not otherwise enforce subtype integrity.

---

**Blob database storage**

Because Blob data are typically large, variably-sized objects of binary or text data, InterBase stores them most efficiently using a method of segmentation. It would be an inefficient use of disk space to store each Blob as one contiguous mass. Instead, InterBase stores each Blob in segments that are indexed by a handle that InterBase generates when you create the Blob. This handle is known as the *Blob ID* and is a quadword (64-bit) containing a unique combination of table identifier and Blob identifier.

The Blob ID for each Blob is stored in its appropriate field in the table record. The Blob ID points to the first segment of the Blob, or to a page of pointers, each of which points to a segment of one or more Blob fields. You can retrieve the Blob ID by executing a `SELECT` statement that specifies the Blob as the target, as in the following example:

```
EXEC SQL
  DECLARE BLOBDESC CURSOR FOR
  SELECT GUIDEBOOK
  FROM TOURISM
  WHERE STATE = 'CA';
```

You define Blob columns the same way you define non-Blob columns.

The following SQL code creates a table with a Blob column called `PROJ_DESC`. It sets the subtype parameter to 1, which denotes a TEXT Blob, and sets the segment size to 80 bytes:

```
CREATE TABLE PROJECT
(
  PROJ_ID PROJNO NOT NULL,
  PROJ_NAME VARCHAR(20) NOT NULL UNIQUE,
  PROJ_DESC BLOB SUBTYPE 1 SEGMENT SIZE 80,
  TEAM_LEADER EMNPO,
  PRODUCT PRODTYPE,
  ...
);
```

The following diagram shows the relationship between a Blob column containing a Blob ID and the Blob data referenced by the Blob ID:
HOW ARE BLOB DATA STORED?

Rather than store Blob data directly in the table, InterBase stores a Blob ID in each row of the table. The Blob ID, a unique number, points to the first segment of the Blob data that is stored elsewhere in the database, in a series of segments. When an application creates a Blob, it must write data to that Blob a segment at a time. Similarly, when an application reads of Blob, it reads a segment at a time. Because most Blob data are large objects, most Blob management is performed with loops in the application code.

Blob segment length

When you define a Blob in a table, you specify the expected size of Blob segments that are to be written to the column in the Blob definition statement. The segment length you define for a Blob column specifies the maximum number of bytes that an application is expected to write to or read from any Blob in the column. The default segment length is 80. For example, the following column declaration creates a Blob with a segment length of 120:

```
EXEC SQL CREATE TABLE TABLE2
{
  Blob1 Blob SEGMENT SIZE 120;
};
```

InterBase uses the segment length setting to determine the size of an internal buffer to which it writes Blob segment data. Normally, you should not attempt to write segments larger than the segment length you defined in the table; doing so may result in a buffer overflow and possible memory corruption.

Specifying a segment size of \( n \) guarantees that no more than \( n \) number of bytes are read or written in a single Blob operation. With some types of operations, for instance, with SELECT, INSERT, and UPDATE operations, you can read or write Blob segments of varying length.

In the following example of an INSERT CURSOR statement, specify the segment length in a host language variable, `segment_length`, as follows:
EXEC SQL
    INSERT CURSOR BCINS VALUES (:write_segment_buffer
    INDICATOR :segment_length);

For more information about the syntax of the INSERT CURSOR statement, see the Language Reference.

**Overriding segment length**

You can override the segment length setting by including the MAXIMUM_SEGMENT option in a DECLARE CURSOR statement. For example, the following Blob INSERT cursor declaration overrides the segment length that was defined for the field, Blob2, increasing it to 1024:

EXEC SQL
    DECLARE BCINS CURSOR FOR INSERT Blob Blob2 INTO TABLE 2
    MAXIMUM_SEGMENT 1024;

**Note** By overriding the segment length setting, you affect only the segment size for the cursor, not for the column, or for other cursors. Other cursors using the same Blob column maintain the original segment size that was defined in the column definition, or can specify their own overrides.

The segment length setting does not affect InterBase system performance. Choose the segment length most convenient for the specific application. The largest possible segment length is 65,535 bytes (64K).

**Accessing Blob data with SQL**

InterBase supports SELECT, INSERT, UPDATE, and DELETE operations on Blob data. The following sections contain brief discussions of example programs. These programs illustrate how to perform standard SQL operations on Blob data.

**Selecting Blob data**

The following example program selects Blob data from the GUIDEBOOK column of the TOURISM table:

1. Declare host-language variables to store the Blob ID, the Blob segment data, and the length of segment data:

   EXEC SQL
BEGIN DECLARE SECTION;
    BASED ON TOURISM.GUIDEBOOK blob_id;
    BASED ON TOURISM.GUIDEBOOK.SEGMENT blob_segment_buf;
    BASED ON TOURISM.STATE state;
    unsigned short blob_seg_len;
EXEC SQL
END DECLARE SECTION;

The BASED ON ... SEGMENT syntax declares a host-language variable, blob_segment_buf, that is large enough to hold a Blob segment during a FETCH operation. For more information about the BASED ON statement, see the Language Reference.

2. Declare a table cursor to select the desired Blob column, in this case the GUIDEBOOK column:

EXEC SQL
    DECLARE TC CURSOR FOR
        SELECT STATE, GUIDEBOOK
        FROM TOURISM
        WHERE STATE = 'CA';

3. Declare a Blob read cursor. A Blob read cursor is a special cursor used for reading Blob segments:

EXEC SQL
    DECLARE BC CURSOR FOR
        READ Blob GUIDEBOOK
        FROM TOURISM;

The segment length of the GUIDEBOOK Blob column is defined as 60, so Blob cursor, BC, reads a maximum of 60 bytes at a time.

To override the segment length specified in the database schema for GUIDEBOOK, use the MAXIMUM_SEGMENT option. For example, the following code restricts each Blob read operation to a maximum of 40 bytes, and SQLCODE is set to 101 to indicate when only a portion of a segment has been read:

EXEC SQL
    DECLARE BC CURSOR FOR
        READ Blob GUIDEBOOK
        FROM TOURISM
        MAXIMUM_SEGMENT 40;

No matter what the segment length setting is, only one segment is read at a time.

4. Open the table cursor and fetch a row of data containing a Blob:
EXEC SQL
  OPEN TC;
EXEC SQL
  FETCH TC INTO :state, :blob_id;

The FETCH statement fetches the STATE and GUIDEBOOK columns into host variables state and blob_id, respectively.

5. Open the Blob read cursor using the Blob ID stored in the blob_id variable, and fetch the first segment of Blob data:

EXEC SQL
  OPEN BC USING :blob_id;
EXEC SQL
  FETCH BC INTO :blob_segment_buf:blob_seg_len;

When the FETCH operation completes, blob_segment_buf contains the first segment of the Blob, and blob_seg_len contains the segment's length, which is the number of bytes copied into blob_segment_buf.

6. Fetch the remaining segments in a loop. SQLCODE should be checked each time a fetch is performed. An error code of 100 indicates that all of the Blob data has been fetched. An error code of 101 indicates that the segment contains additional data:

   while (SQLCODE != 100 || SQLCODE == 101)
   {
     printf("%*.*s", blob_seg_len, blob_seg_len, blob_segment_buf);
     EXEC SQL
       FETCH BC INTO :blob_segment_buf:blob_seg_len;
   }

InterBase produces an error code of 101 when the length of the segment buffer is less than the length of a particular segment.

For example, if the length of the segment buffer is 40 and the length of a particular segment is 60, the first FETCH produces an error code of 101 indicating that data remains in the segment. The second FETCH reads the remaining 20 bytes of data, and produces an SQLCODE of 0, indicating that the next segment is ready to be read, or 100 if this was the last segment in the Blob.

1. Close the Blob read cursor:

   EXEC SQL
     CLOSE BC;

2. Close the table cursor:
EXEC SQL
CLOSE TC;

Inserting Blob data

The following program inserts Blob data into the GUIDEBOOK column of the TOURISM table:

1. Declare host-language variables to store the Blob ID, Blob segment data, and the length of segment data:

   EXEC SQL
   BEGIN DECLARE SECTION;
   BASED ON TOURISM.GUIDEBOOK blob_id;
   BASED ON TOURISM.GUIDEBOOK.SEGMENT blob_segment_buf;
   BASED ON TOURISM.STATE state;
   unsigned short blob_seg_len;
   EXEC SQL
   END DECLARE SECTION;

   The BASED ON … SEGMENT syntax declares a host-language variable, blob_segment_buf, that is large enough to hold a Blob segment during a FETCH operation. For more information about the BASED ON directive, see the Language Reference.

2. Declare a Blob insert cursor:

   EXEC SQL
   DECLARE BC CURSOR FOR INSERT Blob GUIDEBOOK INTO TOURISM;

3. Open the Blob insert cursor and specify the host variable in which to store the Blob ID:

   EXEC SQL
   OPEN BC INTO :blob_id;

4. Store the segment data in the segment buffer, blob_segment_buf, calculate the length of the segment data, and use an INSERT CURSOR statement to write the segment:

   sprintf(blob_segment_buf, ’We hold these truths to be self evident’);
   blob_segment_len = strlen(blob_segment_buf);

   EXEC SQL
   INSERT CURSOR BC VALUES (:blob_segment_buf:blob_segment_len);
Repeat these steps in a loop until you have written all Blob segments.

5. Close the Blob insert cursor:
   
   ```sql
   EXEC SQL
   CLOSE BC;
   ```

6. Use an INSERT statement to insert a new row containing the Blob into the TOURISM table:
   
   ```sql
   EXEC SQL
   INSERT INTO TOURISM (STATE,GUIDEBOOK) VALUES ('CA',:blob_id);
   ```

7. Commit the changes to the database:
   
   ```sql
   EXEC SQL
   COMMIT;
   ```

---

**Updating Blob data**

You cannot update a Blob directly. You must create a new Blob, read the old Blob data into a buffer where you can edit or modify it, then write the modified data to the new Blob.

Create a new Blob by following these steps:

1. Declare a Blob insert cursor:
   
   ```sql
   EXEC SQL
   DECLARE BC CURSOR FOR INSERT BLOB GUIDEBOOK INTO TOURISM;
   ```

2. Open the Blob insert cursor and specify the host variable in which to store the Blob ID:
   
   ```sql
   EXEC SQL
   OPEN BC INTO :blob_id;
   ```

3. Store the old Blob segment data in the segment buffer `blob_segment_buf`, calculate the length of the segment data, perform any modifications to the data, and use an INSERT CURSOR statement to write the segment:
   
   ```sql
   /* Programmatically read the first/next segment of the old Blob * segment data into blob_segment_buf; */
   EXEC SQL
   INSERT CURSOR BC VALUES (:blob_segment_buf:blob_segment_len);
   ```

   Repeat these steps in a loop until you have written all Blob segments.

4. Close the Blob insert cursor:
EXEC SQL
CLOSE BC;

5. When you have completed creating the new Blob, issue an UPDATE statement to replace the old Blob in the table with the new one, as in the following example:

EXEC SQL UPDATE TOURISM
SET
  GUIDEBOOK = :blob_id;
WHERE CURRENT OF TC;

Note The TC table cursor points to a target row established by declaring the cursor and then fetching the row to update.

To modify a text Blob using this technique, you might read an existing Blob field into a host-language buffer, modify the data, then write the modified buffer over the existing field data with an UPDATE statement.

---

**Deleting Blob data**

There are two methods for deleting a Blob. The first is to delete the row containing the Blob. The second is to update the row and set the Blob column to NULL or to the Blob ID of a different Blob (for example, the new Blob created to update the data of an existing Blob).

The following statement deletes current Blob data in the GUIDEBOOK column of the TOURISM table by setting it to NULL:

EXEC SQL UPDATE TOURISM
SET
  GUIDEBOOK = NULL;
WHERE CURRENT OF TC;

Blob data is not immediately deleted when DELETE is specified. The actual delete operation occurs when InterBase performs version cleanup. The following code fragment illustrates how to recover space after deleting a Blob:

EXEC SQL
  UPDATE TABLE SET Blob_COLUMN = NULL WHERE ROW = :myrow;
EXEC SQL
  COMMIT;
  /* wait for all active transactions to finish */
  /* force a sweep of the database */
When InterBase performs garbage collection on old versions of a record, it verifies whether or not recent versions of the record reference the Blob ID. If the record does not reference the Blob ID, InterBase cleans up the Blob.

### Accessing Blob data with API calls

In addition to accessing Blob data using SQL as described in this chapter, the InterBase API provides routines for accessing Blob data. The following API calls are provided for accessing and managing Blob data:

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>isc_blob_default_desc()</code></td>
<td>Loads a Blob descriptor data structure with default information about a Blob.</td>
</tr>
<tr>
<td><code>isc_blob_gen_bpb()</code></td>
<td>Generates a Blob parameter buffer (BPB) from source and target Blob descriptors to allow dynamic access to Blob subtype and character set information.</td>
</tr>
<tr>
<td><code>isc_blob_info()</code></td>
<td>Returns information about an open Blob.</td>
</tr>
<tr>
<td><code>isc_blob_lookup_desc()</code></td>
<td>Looks up and stores into a Blob descriptor the subtype, character set, and segment size of a Blob.</td>
</tr>
<tr>
<td><code>isc_blob_set_desc()</code></td>
<td>Sets the fields of a Blob descriptor to values specified in parameters to <code>isc_blob_set_desc()</code>.</td>
</tr>
<tr>
<td><code>isc_cancel_blob()</code></td>
<td>Discards a Blob and frees internal storage.</td>
</tr>
<tr>
<td><code>isc_close_blob()</code></td>
<td>Closes an open Blob.</td>
</tr>
<tr>
<td><code>isc_create_blob2()</code></td>
<td>Creates a context for storing a Blob, opens the Blob for write access, and optionally specifies a filter to be used to translate the Blob data from one subtype to another.</td>
</tr>
<tr>
<td><code>isc_get_segment()</code></td>
<td>Reads a segment from an open Blob.</td>
</tr>
<tr>
<td><code>isc_open_blob2()</code></td>
<td>Opens an existing Blob for retrieval and optional filtering.</td>
</tr>
<tr>
<td><code>isc_put_segment()</code></td>
<td>Writes a Blob segment.</td>
</tr>
</tbody>
</table>

**TABLE 8.2** API Blob calls

For details on using the API calls to access Blob data, see the *API Guide*. 
Filtering Blob data

An understanding of Blob subtypes is particularly important when working with Blob filters. A Blob filter is a routine that translates Blob data from one subtype to another. InterBase includes a set of special internal Blob filters that convert from subtype 0 to subtype 1 (TEXT), and from subtype 1 (TEXT) to subtype 0. In addition to using these standard filters, you can write your own external filters to provide special data translation. For example, you might develop a filter to translate bitmapped images from one format to another.

IMPORTANT Blob filters are available for databases residing on all InterBase server platforms except NetWare, where Blob filters cannot be created or used.

Using the standard InterBase text filters

The standard InterBase filters convert Blob data of subtype 0, or any InterBase system type, to subtype 1 (TEXT).

When a text filter is being used to read data from a Blob column, it modifies the standard InterBase behavior for supplying segments. Regardless of the actual nature of the segments in the Blob column, the text filter enforces the rule that segments must end with a newline character (\n).

The text filter returns all the characters up to and including the first newline as the first segment, the next characters up to and including the second newline as the second segment, and so on.

Tip To convert any non-text subtype to TEXT, declare its FROM subtype as subtype 0 and its TO subtype as subtype 1.

Using an external Blob filter

Unlike the standard InterBase filters that convert between subtype 0 and subtype 1, an external Blob filter is generally part of a library of routines you create and link to your application.

To use an external filter, you must first write it, compile and link it, then declare it to the database that contains the Blob data you want processed.
Declaring an external filter to the database

To declare an external filter to a database, use the DECLARE FILTER statement. For example, the following statement declares the filter, SAMPLE:

```sql
EXEC SQL
DECLARE FILTER SAMPLE
INPUT_TYPE -1 OUTPUT_TYPE -2
ENTRY_POINT 'FilterFunction'
MODULE_NAME 'filter.dll';
```

In the example, the filter's input subtype is defined as -1 and its output subtype as -2. In this example, INPUT_TYPE specifies lowercase text and OUTPUT_TYPE specifies uppercase text. The purpose of filter, SAMPLE, therefore, is to translate Blob data from lowercase text to uppercase text.

The ENTRY_POINT and MODULE_NAME parameters specify the external routine that InterBase calls when the filter is invoked. The MODULE_NAME parameter specifies filter.dll, the dynamic link library containing the filter's executable code. The ENTRY_POINT parameter specifies the entry point into the DLL. The example shows only a simple file name. It is good practice to specify a fully-qualified path name, since users of your application need to load the file.

Using a filter to read and write Blob data

The following illustration shows the default behavior of the SAMPLE filter that translates from lowercase text to uppercase text.

![Diagram of filtering from lowercase to uppercase](image)

Similarly, when reading data, the SAMPLE filter can easily read Blob data of subtype -2, and translate it to data of subtype -1.
Invoking a filter in an application

To invoke a filter in an application, use the FILTER option when declaring a Blob cursor. Then, when the application performs operations using the cursor, InterBase automatically invokes the filter.

For example, the following INSERT cursor definition specifies that the filter, SAMPLE, is to be used in any operations involving the cursor, BCINS1:

```
EXEC SQL
    DECLARE BCINS1 CURSOR FOR
    INSERT Blob Blob1 INTO TABLE1
    FILTER FROM -1 TO -2;
```

When InterBase processes this declaration, it searches a list of filters defined in the current database for a filter with matching FROM and TO subtypes. If such a filter exists, InterBase invokes it during Blob operations that use the cursor, BCINS1. If InterBase cannot locate a filter with matching FROM and TO subtypes, it returns an error to the application.

Writing an external Blob filter

If you choose to write your own filters, you must have a detailed understanding of the datatypes you plan to translate. As mentioned elsewhere in this chapter, InterBase does not do strict datatype checking on Blob data, but does enforce the rule that Blob source and target subtypes must be compatible. Maintaining and enforcing this compatibility is your responsibility.
**Filter types**

Filters can be divided into two types: filters that convert data one segment at a time, and filters that convert data many segments at a time.

The first type of filter reads a segment of data, converts it, and supplies it to the application a segment at a time.

The second type of filter might read all the data and do all the conversion when the Blob read cursor is first opened, and then simulate supplying data a segment at a time to the application.

If timing is an issue for your application, you should carefully consider these two types of filters and which might better serve your purpose.

**Read-only and write-only filters**

Some filters support only reading from or only writing to a Blob, but not both operations. If you attempt to use a Blob filter for an operation that it does not support, InterBase returns an error to the application.

**Defining the filter function**

When writing your filter, you must include an entry point, known as a *filter function*, in the declaration section of the program. InterBase calls the filter function when your application performs a Blob access operation. All communication between InterBase and the filter is through the filter function. The filter function itself may call other functions that comprise the filter executable.
Declare the name of the filter function and the name of the filter executable with the ENTRY_POINT and MODULE_NAME parameters of the DECLARE FILTER statement.

A filter function must have the following declaration *calling sequence*:

```c
filter_function_name(short action, isc_blob_ctl control);
```

The parameter, *action*, is one of eight possible action macro definitions and the parameter, *control*, is an instance of the *isc_blob_ctl* Blob control structure, defined in the InterBase header file *ibase.h*. These parameters are discussed later in this chapter.

The following listing of a skeleton filter declares the filter function, *jpeg_filter*:

```c
#include <ibase.h>

#define SUCCESS 0
#define FAILURE 1

ISC_STATUS jpeg_filter(short action, isc_blob_ctl control) {  
    ISC_STATUS status = SUCCESS;
    switch (action) {
        case isc_blob_filter_open:
        . . .  
        break;
        case isc_blob_filter_get_segment:
        . . .  
        break;
        case isc_blob_filter_create:
        . . .
    }
```
break;
case isc_blob_filter_put_segment:
  .  .  .
  break;
case isc_blob_filter_close:
  .  .  .
  break;
case isc_blob_filter_alloc:
  .  .  .
  break;
case isc_blob_filter_free:
  .  .  .
  break;
case isc_blob_filter_seek:
  .  .  .
  break;
default:
  status = isc_uns_ext /* unsupported action value */
  .  .  .
  break;
}
return status;
}

InterBase passes one of eight possible actions to the filter function, \texttt{jpeg\_filter()}, by way of the \texttt{action} parameter, and also passes an instance of the Blob control structure, \texttt{isc\_blob\_ctl}, by way of the parameter \texttt{control}.

The ellipses (…) in the previous listing represent code that performs some operations based on each action, or event, that is listed in the case statement. Each action is a particular event invoked by a database operation the application might perform. For more information, see \textit{``Programming filter function actions'' on page 211.}

The \texttt{isc\_blob\_ctl} Blob control structure provides the fundamental data exchange between InterBase and the filter. For more information on the Blob control structure, see \textit{``Defining the Blob control structure'' on page 208.}

\textbf{Defining the Blob control structure}

The Blob control structure, \texttt{isc\_blob\_ctl}, provides the fundamental method of data exchange between InterBase and a filter. The declaration for the \texttt{isc\_blob\_ctl} control structure is in the InterBase include file, \texttt{ibase.h}.
The `isc_blob_ctl` structure is used in two ways:

1. When the application performs a Blob access operation, InterBase calls the filter function and passes it an instance of `isc_blob_ctl`.
2. Internal filter functions can pass an instance of `isc_blob_ctl` to internal InterBase access routines.

In either case, the purpose of certain `isc_blob_ctl` fields depends on the action being performed.

For example, when an application attempts a Blob INSERT, InterBase passes an `isc_blob_filter_put_segment` action to the filter function. The filter function passes an instance of the control structure to InterBase. The `ctl_buffer` of the structure contains the segment data to be written, as specified by the application in its Blob INSERT statement. Because the buffer contains information to pass into the filter function, it is called an `in` field. The filter function should include instructions in the case statement under the `isc_blob_filter_put_segment` case for performing the write to the database.

In a different case, for instance when an application attempts a FETCH operation, the case of an `isc_blob_filter_get_segment` action should include instructions for filling `ctl_buffer` with segment data from the database to return to the application. In this case, because the buffer is used for filter function output, it is called an `out` field.

The following table describes each of the fields in the `isc_blob_ctl` Blob control structure, and whether they are used for filter function input (`in`), or output (`out`).

<table>
<thead>
<tr>
<th>Field name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(*ctl_source)()</td>
<td>Pointer to the internal InterBase Blob access routine. (<code>in</code>)</td>
</tr>
<tr>
<td>*ctl_source_handle</td>
<td>Pointer to an instance of <code>isc_blob_ctl</code> to be passed to the internal InterBase Blob access routine. (<code>in</code>)</td>
</tr>
<tr>
<td>ctl_to_sub_type</td>
<td>Target subtype. Information field. Provided to support multi-purpose filters that can perform more than one kind of translation. This field and the next one enable such a filter to decide which translation to perform. (<code>in</code>)</td>
</tr>
<tr>
<td>ctl_from_sub_type</td>
<td>Source subtype. Information field. Provided to support multi-purpose filters that can perform more than one kind of translation. This field and the previous one enable such a filter to decide which translation to perform. (<code>in</code>)</td>
</tr>
<tr>
<td>ctl_buffer_length</td>
<td>For <code>isc_blob_filter_put_segment</code>, field is an <code>in</code> field that contains the length of the segment data contained in <code>ctl_buffer</code>. For <code>isc_blob_filter_get_segment</code>, field is an <code>in</code> field set to the size of the buffer pointed to by <code>ctl_buffer</code>, which is used to store the retrieved Blob data.</td>
</tr>
</tbody>
</table>

**TABLE 8.3** `isc_blob_ctl` structure field descriptions
CHAPTER 8 WORKING WITH BLOB DATA

SETTING CONTROL STRUCTURE INFORMATION FIELD VALUES

The `isc_blob_ctl` structure contains three fields that store information about the Blob currently being accessed: `ctl_max_segment`, `ctl_number_segments`, and `ctl_total_length`. You should attempt to maintain correct values for these fields in the filter function, whenever possible. Depending on the purpose of the filter, maintaining correct values for the fields is not always possible. For example, a filter that compresses data on a segment-by-segment basis cannot determine the size of `ctl_max_segment` until it processes all segments.

<table>
<thead>
<tr>
<th>Field name</th>
<th>Description</th>
</tr>
</thead>
</table>
| `ctl_segment_length` | Length of the current segment. This field is not used for `isc_blob_filter_put_segment`.  
For `isc_blob_filter_get_segment`, the field is an OUT field set to the size of the retrieved segment (or partial segment, in the case when the buffer length `ctl_buffer_length` is less than the actual segment length). |
| `ctl_bpb_length` | Length of the Blob parameter buffer. Reserved for future enhancement. |
| `*ctl_bpb`     | Pointer to a Blob parameter buffer. Reserved for future enhancement. |
| `*ctl_buffer`  | Pointer to a segment buffer. For `isc_blob_filter_put_segment`, field is an in field that contains the segment data.  
For `isc_blob_filter_get_segment`, the field is an OUT field the filter function fills with segment data for return to the application. |
| `ctl_max_segment` | Length of longest segment in the Blob. Initial value is 0. The filter function sets this field. This field is informational only. |
| `ctl_number_segments` | Total number of segments in the Blob. Initial value is 0. The filter function sets this field. This field is informational only. |
| `ctl_total_length` | Total length of the Blob. Initial value is 0. The filter function sets this field. This field is informational only. |
| `*ctl_status`  | Pointer to the InterBase status vector. (OUT) |
| `ctl_data[8]`  | 8-element array of application-specific data. Use this field to store resource pointers, such as memory pointers and file handles created by the `isc_blob_filter_open` handler, for example. Then, the next time the filter function is called, the resource pointers will be available for use. (IN/OUT) |

TABLE 8.3 `isc_blob_ctl` structure field descriptions (continued)
These fields are informational only. InterBase does not use the values of these fields in internal processing.

### Programming filter function actions

When an application performs a Blob access operation, InterBase passes a corresponding action message to the filter function by way of the *action* parameter. There are eight possible actions, each of which results from a particular access operation. The following list of action macro definitions are declared in the `ibase.h` file:

```c
#define isc_blob_filter_open        0
#define isc_blob_filter_get_segment 1
#define isc_blob_filter_close       2
#define isc_blob_filter_create      3
#define isc_blob_filter_put_segment 4
#define isc_blob_filter_alloc       5
#define isc_blob_filter_free        6
#define isc_blob_filter_seek        7
```

The following table describes the Blob access operation that corresponds to each action:

<table>
<thead>
<tr>
<th>Action</th>
<th>Invoked when …</th>
<th>Use to …</th>
</tr>
</thead>
</table>
| `isc_blob_filter_open` | Application opens a Blob READ cursor | Set the information fields of the Blob control structure.  
Perform initialization tasks, such as allocating memory or opening temporary files.  
Set the status variable, if necessary. The value of the status variable becomes the filter function’s return value. |
| `isc_blob_filter_get_segment` | Application executes a Blob FETCH statement | Set the `ctl_buffer` and `ctl_segment_length` fields of the Blob control structure to contain a segment’s worth of translated data on the return of the filter function.  
Perform the data translation if the filter processes the Blob segment-by-segment.  
Set the status variable. The value of the status variable becomes the filter function’s return value. |
| `isc_blob_filter_close` | Application closes a Blob cursor | Perform exit tasks, such as freeing allocated memory, closing, or removing temporary files. |
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<table>
<thead>
<tr>
<th>Action</th>
<th>Invoked when …</th>
<th>Use to …</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>isc_blob_filter_create</em></td>
<td>Application opens a Blob INSERT cursor</td>
<td>Set the information fields of the Blob control structure.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Perform initialization tasks, such as allocating memory or opening temporary files.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Set the status variable, if necessary. The value of the status variable becomes the filter function's return value.</td>
</tr>
<tr>
<td><em>isc_blob_filter_put_segment</em></td>
<td>Application executes a Blob INSERT statement</td>
<td>Perform the data translation on the segment data passed in through the Blob control structure.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Write the segment data to the database. If the translation process changes the segment length, the new value must be reflected in the values passed to the writing function.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Set the status variable. The value of the status variable becomes the filter function's return value.</td>
</tr>
<tr>
<td><em>isc_blob_filter_alloc</em></td>
<td>InterBase initializes filter processing; not a result of a particular application action</td>
<td>Set the information fields of the Blob control structure.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Perform initialization tasks, such as allocating memory or opening temporary files.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Set the status variable, if necessary. The value of the status variable becomes the filter function's return value.</td>
</tr>
<tr>
<td><em>isc_blob_filter_free</em></td>
<td>InterBase ends filter processing; not a result of a particular application action</td>
<td>Perform exit tasks, such as freeing allocated memory, closing, or removing temporary files.</td>
</tr>
<tr>
<td><em>isc_blob_filter_seek</em></td>
<td>Reserved for internal filter use; not used by external filters</td>
<td></td>
</tr>
</tbody>
</table>

**Tip** Store resource pointers, such as memory pointers and file handles created by the *isc_blob_filter_open* handler, in the *ctl_data* field of the *isc_blob_ctl* Blob control structure. Then, the next time the filter function is called, the resource pointers are still available.

**TABLE 8.4 Blob access operations (continued)**
Testing the function return value

The filter function must return an integer indicating the status of the operation it performed. You can have the function return any InterBase status value returned by an internal InterBase routine.

In some filter applications, a filter function has to supply status values directly. The following table lists status values that apply particularly to Blob processing:

<table>
<thead>
<tr>
<th>Macro constant</th>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUCCESS</td>
<td>0</td>
<td>Indicates the filter action has been handled successfully. On a Blob read (isc_blob_filter_get_segment) operation, indicates that the entire segment has been read.</td>
</tr>
<tr>
<td>FAILURE</td>
<td>1</td>
<td>Indicates an unsuccessful operation. In most cases, a status more specific to the error is returned.</td>
</tr>
<tr>
<td>isc_uns_ext</td>
<td>See ibase.h</td>
<td>Indicates that the attempted action is unsupported by the filter. For example, a read-only filter would return isc_uns_ext for an isc_blob_filter_put_segment action.</td>
</tr>
<tr>
<td>isc_segment</td>
<td>See ibase.h</td>
<td>During a Blob read operation, indicates that the supplied buffer is not large enough to contain the remaining bytes in the current segment. In this case, only ctl_buffer_length bytes are copied, and the remainder of the segment must be obtained through additional isc_blob_filter_get_segment calls.</td>
</tr>
<tr>
<td>isc_segstr_eof</td>
<td>See ibase.h</td>
<td>During a Blob read operation, indicates that the end of the Blob has been reached; there are no additional segments remaining to be read.</td>
</tr>
</tbody>
</table>

TABLE 8.5 Blob filter status values

For more information about InterBase status values, see the Language Reference.
InterBase supports arrays of most datatypes. Using an array enables multiple data items to be stored in a single column. InterBase can treat an array as a single unit, or as a series of separate units, called *slices*. Using an array is appropriate when:

- The data items naturally form a set of the same datatype
- The entire set of data items in a single database column must be represented and controlled as a unit, as opposed to storing each item in a separate column
- Each item must also be identified and accessed individually

The data items in an array are called *array elements*. An array can contain elements of any InterBase datatype except BLOB. It cannot be an array of arrays, although InterBase *does* support multidimensional arrays. All of the elements of an array must be of the same datatype.
**Creating arrays**

Arrays are defined with the `CREATE DOMAIN` or `CREATE TABLE` statements. Defining an array column is just like defining any other column, except that you must also specify the array dimensions.

Array indexes range from $-2^{31}$ to $+2^{31}-1$.

The following statement defines a regular character column and a single-dimension, character array column containing four elements:

```sql
EXEC SQL
CREATE TABLE TABLE1
(
  NAME CHAR(10),
  CHAR_ARR CHAR(10)[4]
);
```

Array dimensions are always enclosed in square brackets following a column’s datatype specification.

For a complete discussion of `CREATE TABLE` and array syntax, see the *Language Reference*.

---

**Multi-dimensional arrays**

InterBase supports *multi-dimensional arrays*, arrays with 1 to 16 dimensions. For example, the following statement defines three integer array columns with two, three, and six dimensions, respectively:

```sql
EXEC SQL
CREATE TABLE TABLE1
(
  INT_ARR2 INTEGER[4,5]
  INT_ARR3 INTEGER[4,5,6]
  INT_ARR6 INTEGER[4,5,6,7,8,9]
);
```

In this example, `INT_ARR2` allocates storage for 4 rows, 5 elements in width, for a total of 20 integer elements, `INT_ARR3` allocates 120 elements, and `INT_ARR6` allocates 60,480 elements.
**IMPORTANT** InterBase stores multi-dimensional arrays in row-major order. Some host languages, such as FORTRAN, expect arrays to be in column-major order. In these cases, care must be taken to translate element ordering correctly between InterBase and the host language.

---

**Specifying subscript ranges**

In InterBase, array dimensions have a specific range of upper and lower boundaries, called *subscripts*. In many cases, the subscript range is implicit: the first element of the array is element 1, the second element 2, and the last is element \( n \). For example, the following statement creates a table with a column that is an array of four integers:

```sql
EXEC SQL
CREATE TABLE TABLE1
(
    INT_ARR INTEGER[4]
);
```

The subscripts for this array are 1, 2, 3, and 4.

A different set of upper and lower boundaries for each array dimension can be explicitly defined when an array column is created. For example, C programmers, familiar with arrays that start with a lower subscript boundary of zero, may want to create array columns with a lower boundary of zero as well.

To specify array subscripts for an array dimension, both the lower and upper boundaries of the dimension must be specified using the following syntax:

```
lower:upper
```

For example, the following statement creates a table with a single-dimension array column of four elements where the lower boundary is 0 and the upper boundary is 3:

```sql
EXEC SQL
CREATE TABLE TABLE1
(
    INT_ARR INTEGER[0:3]
);
```

The subscripts for this array are 0, 1, 2, and 3.

When creating multi-dimensional arrays with explicit array boundaries, separate each dimension's set of subscripts from the next with commas. For example, the following statement creates a table with a two-dimensional array column where each dimension has four elements with boundaries of 0 and 3:

```sql
EXEC SQL
CREATE TABLE TABLE1
(
    INT_ARR INTEGER[0:3,0:3]
);
```
EXEC SQL
CREATE TABLE TABLE1
(
    INT.ARR INTEGER[0:3, 0:3]
);

Accessing arrays

InterBase can perform operations on an entire array, effectively treating it as a single element, or it can operate on an array slice, a subset of array elements. An array slice can consist of a single element, or a set of many contiguous elements.

InterBase supports the following data manipulation operations on arrays:

- Selecting data from an array
- Inserting data into an array
- Updating data in an array slice
- Selecting data from an array slice
- Evaluating an array element in a search condition

A user-defined function (UDF) can only reference a single array element.

The following array operations are not supported:

- Referencing array dimensions dynamically in DSQL
- Inserting data into an array slice
- Setting individual array elements to NULL
- Using the aggregate functions, MIN(), MAX(), SUM(), AVG(), and COUNT() with arrays
- Referencing arrays in the GROUP BY clause of a SELECT
- Creating views that select from array slices

Selecting data from an array

To select data from an array, perform the following steps:

1. Declare a host-language array variable of the correct size to hold the array data. For example, the following statements create three such variables:

   EXEC SQL
   BEGIN DECLARE SECTION;
2. Declare a cursor that specifies the array columns to select. For example,

```sql
EXEC SQL
DECLARE TC1 CURSOR FOR
SELECT NAME, CHAR_ARR[], INT_ARR[]
FROM TABLE1;
```

Be sure to include brackets ([]) after the array column name to select the array data. If the brackets are left out, InterBase reads the array ID for the column, instead of the array data.

The ability to read the array ID, which is actually a Blob ID, is included only to support applications that access array data using InterBase API calls.

3. Open the cursor, and fetch data:

```sql
EXEC SQL
OPEN TC1;
EXEC SQL
FETCH TC1 INTO :name, :char_arr, :int_arr;
```

**Note** It is not necessary to use a cursor to select array data. For example, a singleton SELECT might be appropriate, too.

When selecting array data, keep in mind that InterBase stores elements in row-major order. For example, in a 2-dimensional array, with 2 rows and 3 columns, all 3 elements in row 1 are returned, then all three elements in row two.

---

**Inserting data into an array**

INSERT can be used to insert data into an array column. The data to insert must exactly fill the entire array, or an error can occur.

To insert data into an array, follow these steps:

1. Declare a host-language variable to hold the array data. Use the BASED ON clause as a handy way of declaring array variables capable of holding data to insert into the entire array. For example, the following statements create three such variables:

```sql
EXEC SQL
BASSED ON TABLE1.CHAR_ARR  char_arr;
BASSED ON TABLE1.INT_ARR   int_arr;
BASSED ON TABLE1.FLOAT_ARR float_arr;
EXEC SQL
END DECLARE SECTION;
```
BEGIN DECLARE SECTION;
    BASED ON TABLE1.CHAR_ARR  char_arr;
    BASED ON TABLE1.INT_ARR    int_arr;
    BASED ON TABLE1.FLOAT_ARR  float_arr;
EXEC SQL
END DECLARE SECTION;

2. Load the host-language variables with data.
3. Use INSERT to write the arrays. For example,
   EXEC SQL
       INSERT INTO TABLE1 (NAME, CHAR_ARR, INT_ARR, FLOAT_ARR)
       VALUES ('Sample', :char_arr, :int_arr, :float_arr);
4. Commit the changes:
   EXEC SQL
   COMMIT;

IMPORTANT When inserting data into an array column, provide data to fill all array elements, or the
results will be unpredictable.

---

**Selecting from an array slice**

The SELECT statement supports syntax for retrieving contiguous ranges of elements from
arrays. These ranges are referred to as *array slices*. Array slices to retrieve are specified
in square brackets ([]) following a column name containing an array. The number inside
the brackets indicates the elements to retrieve. For a one-dimensional array, this is a
single number. For example, the following statement selects the second element in a
one-dimensional array:

   EXEC SQL
   SELECT JOB_TITLE[2]
   INTO :title
   FROM EMPLOYEE
   WHERE LAST_NAME = :lname;

To retrieve a subset of several contiguous elements from a one-dimensional array, specify
both the first and last elements of the range to retrieve, separating the values with a colon.
The syntax is as follows:

   [lower_bound:upper_bound]

For example, the following statement retrieves a subset of three elements from a
one-dimensional array:
EXEC SQL
  SELECT JOB_TITLE[2:4]
    INTO :title
  FROM EMPLOYEE
  WHERE LAST_NAME = :lname;

For multi-dimensional arrays, the lower and upper values for each dimension must be specified, separated from one another by commas, using the following syntax:

[lower:upper, lower:upper [, lower:upper ...]]

**Note** In this syntax, the bold brackets must be included.

For example, the following statement retrieves two rows of three elements each:

EXEC SQL
DECLARE TC2 CURSOR FOR
  SELECT INT_ARR[1:2,1:3]
  FROM TABLE1

Because InterBase stores array data in row-major order, the first range of values between the brackets specifies the subset of rows to retrieve. The second range of values specifies which elements in each row to retrieve.

To select data from an array slice, perform the following steps:

1. Declare a host-language variable large enough to hold the array slice data retrieved. For example,

   EXEC SQL
   BEGIN DECLARE SECTION;
   char char_slice[11]; /* 11-byte string for CHAR(10) datatype */
   long int_slice[2][3];
   EXEC SQL
   END DECLARE SECTION;

   The first variable, *char_slice*, is intended to store a single element from the CHAR_ARR column. The second example, *int_slice*, is intended to store a six-element slice from the INT_ARR integer column.

2. Declare a cursor that specifies the array slices to read. For example,

   EXEC SQL
   DECLARE TC2 CURSOR FOR
   SELECT CHAR_ARR[1], INT_ARR[1:2,1:3]
   FROM TABLE1

3. Open the cursor, and the fetch data:
Executing SQL
OPEN TC2;
EXEC SQL
FETCH TC2 INTO :char_slice, :int_slice;

### Updating data in an array slice

A subset of elements in an array can be updated with a cursor. To perform an update, follow these steps:

1. Declare a host-language variable to hold the array slice data. For example,

   ```sql
   BEGIN DECLARE SECTION;
   char char_slice[11]; /* 11-byte string for CHAR(10) datatype */
   long int_slice[2][3];
   END DECLARE SECTION;
   ```

   The first variable, `char_slice`, is intended to hold a single element of the CHAR_ARR array column defined in the programming example in the previous section. The second example, `int_slice`, is intended to hold a six-element slice of the INT_ARR integer array column.

2. Select the row that contains the array data to modify. For example, the following cursor declaration selects data from the INT_ARRAY and CHAR_ARRAY columns:

   ```sql
   DECLARE TC1 CURSOR FOR
   SELECT CHAR_ARRAY[1], INT_ARRAY[1:2,1:3] FROM TABLE1;
   ```

   ```sql
   OPEN TC1;
   ```

   ```sql
   FETCH TC1 INTO :char_slice, :int_slice;
   ```

   This example fetches the data currently stored in the specified slices of CHAR_ARRAY and INT_ARRAY, and stores it into the `char_slice` and `int_slice` host-language variables, respectively.

3. Load the host-language variables with new or updated data.
4. Execute an UPDATE statement to insert data into the array slices. For example, the following statements put data into parts of CHAR_ARRAY and INT_ARRAY, assuming char_slice and int_slice contain information to insert into the table:

```sql
EXEC SQL
UPDATE TABLE1
SET
  CHAR_ARR[1] = :char_slice,
  INT_ARR[1:2,1:3] = :int_slice
WHERE CURRENT OF TC1;
```

5. Commit the changes:

```sql
EXEC SQL
COMMIT;
```

The following fragment of the output from this example illustrates the contents of the columns, CHAR_ARR and INT_ARR after this operation.

<table>
<thead>
<tr>
<th>char_arr values:</th>
<th>int_arr values:</th>
</tr>
</thead>
<tbody>
<tr>
<td>[0]:string0</td>
<td>[0][0]:10</td>
</tr>
<tr>
<td>[1]:NewString</td>
<td>[0][1]:1</td>
</tr>
<tr>
<td>[2]:string2</td>
<td>[0][2]:2</td>
</tr>
<tr>
<td>[3]:string3</td>
<td>[0][3]:3</td>
</tr>
<tr>
<td></td>
<td>[1][0]:100</td>
</tr>
<tr>
<td></td>
<td>[1][1]:999</td>
</tr>
<tr>
<td></td>
<td>[1][2]:999</td>
</tr>
<tr>
<td></td>
<td>[1][3]:999</td>
</tr>
<tr>
<td></td>
<td>[2][0]:100</td>
</tr>
<tr>
<td></td>
<td>[2][1]:999</td>
</tr>
<tr>
<td></td>
<td>[2][2]:999</td>
</tr>
<tr>
<td></td>
<td>[2][3]:999</td>
</tr>
<tr>
<td></td>
<td>[3][0]:100</td>
</tr>
<tr>
<td></td>
<td>[3][1]:999</td>
</tr>
<tr>
<td></td>
<td>[3][2]:999</td>
</tr>
<tr>
<td></td>
<td>[3][3]:999</td>
</tr>
</tbody>
</table>

**Testing a value in a search condition**

A single array element's value can be evaluated in the search condition of a WHERE clause. For example,

```sql
EXEC SQL
DECLARE TC2 CURSOR FOR
  SELECT CHAR_ARR[1], INT_ARR[1:2,1:3]
  FROM TABLE1
  WHERE SMALLINT_ARR[1,1,1] = 111;
```

**IMPORTANT** You cannot evaluate multi-element array slices.
Using host variables in array subscripts

Integer host variables can be used as array subscripts. For example, the following cursor declaration uses host variables, `getval`, and `testval`, in array subscripts:

```
EXEC SQL
DECLARE TC2 CURSOR FOR
      SELECT CHAR_ARR[1], INT_ARR[:getval:1,1:3]
      FROM TABLE1
      WHERE FLOAT_ARR[:testval,1,1] = 111.0;
```

Using arithmetic expressions with arrays

Arithmetic expressions involving arrays can be used only in search conditions. For example, the following code fetches a row of array data at a time that meets the search criterion:

```
for (i = 1; i < 100 && SQLCODE == 0; i++)
{
   EXEC SQL
     SELECT ARR[:i] INTO :array_var
     FROM TABLE1
     WHERE ARR1[:j + 1] = 5;
   process_array(array_var);
}
```
A stored procedure is a self-contained set of extended SQL statements stored in a database as part of its metadata.

Applications can interact with stored procedures in the following ways:

- They can pass parameters to and receive return values from stored procedures.
- They can invoke stored procedures directly to perform a task.
- They can substitute an appropriate stored procedure for a table or view in a SELECT statement.

The advantages of using stored procedures are:

- Applications can share code. A common piece of SQL code written once and stored in the database can be used in any application that accesses the database, including the new InterBase interactive SQL tool, isql.
- Modular design. Stored procedures can be shared among applications, eliminating duplicate code, and reducing the size of applications.
- Streamlined maintenance. When a procedure is updated, the changes are automatically reflected in all applications that use it without the need to recompile and relink them.
CHAPTER 10 WORKING WITH STORED PROCEDURES

- Improved performance, especially for remote client access. Stored procedures are executed by the server, not the client.

This chapter describes how to call and execute stored procedures in applications once they are written. For information on how to create a stored procedure, see the *Data Definition Guide*.

**Using stored procedures**

There are two types of procedures that can be called from an application:

- **Select procedures** that an application can use in place of a table or view in a SELECT statement. A select procedure must return one or more values, or an error results.

- **Executable procedures** that an application can call directly, with the EXECUTE PROCEDURE statement. An executable procedure may or may not return values to the calling program.

Both kinds of procedures are defined with CREATE PROCEDURE and have the same syntax. The difference is in how the procedure is written and how it is intended to be used. Select procedures always return zero or more rows, so that to the calling program they appear as a table or view. Executable procedures are simply routines invoked by the calling program that can return only a single set of values.

In fact, a single procedure conceivably can be used as a select procedure or an executable procedure, but this is not recommended. In general a procedure is written specifically to be used in a SELECT statement (a select procedure) or to be used in an EXECUTE PROCEDURE statement (an executable procedure). For more information on creating stored procedures, see the *Data Definition Guide*.

**Procedures and transactions**

Procedures operate within the context of a transaction in the program that uses them. If procedures are used in a transaction, and the transaction is rolled back, then any actions performed by the procedures are also rolled back. Similarly, a procedure’s actions are not final until its controlling transaction is committed.
Security for procedures

When an application calls a stored procedure, the person running the application must have EXECUTE privilege on the stored procedure. An extension to the GRANT statement enables assignment of EXECUTE privilege, and an extension to the REVOKE statement enables removal of the privilege. For more information about granting privileges to users, see the Data Definition Guide.

In addition, if the stored procedure accesses objects in the database, one of two things must be true: either the user running the application or the called stored procedure must have the appropriate permissions on the accessed objects. The GRANT statement assigns privileges to procedures, and REVOKE eliminates privileges.

Using select procedures

A select procedure is used in place of a table or view in a SELECT statement and can return zero or more rows. A select procedure must return one or more output parameters, or an error results. If returned values are not specified, NULL values are returned by default.

The advantages of select procedures over tables or views are:

- They can take input parameters that can affect the output produced.
- They can contain control statements, local variables, and data manipulation statements, offering great flexibility to the user.

Input parameters are passed to a select procedure in a comma-delimited list in parentheses following the procedure name.

The following isql script defines the procedure, GET_EMP_PROJ, which returns EMP_PROJ, the project numbers assigned to an employee, when passed the employee number, EMP_NO, as the input parameter:

```sql
SET TERM !! ;
CREATE PROCEDURE GET_EMP_PROJ (emp_no SMALLINT)
RETURNS (emp_proj SMALLINT) AS
BEGIN
  FOR SELECT PROJ_ID
    FROM EMPLOYEE_PROJECT
    WHERE EMP_NO = :emp_no
    INTO :emp_proj
  DO
```
The following statement retrieves PROJ_ID from the above procedure, passing the host variable, number, as input:

```
SELECT PROJ_ID FROM GET_EMP_PROJ (:number);
```

### Calling a select procedure

To use a select procedure in place of a table or view name in an application, use the procedure name anywhere a table or view name is appropriate. Supply any input parameters required in a comma-delimited list in parentheses following the procedure name.

```
EXEC SQL
    SELECT PROJ_ID FROM GET_EMP_PROJ (:emp_no)
    ORDER BY PROJ_ID;
```

**IMPORTANT** InterBase does not support creating a view by calling a select procedure.

### Using a select procedure with cursors

A select procedure can also be used in a cursor declaration. For example, the following code declares a cursor named PROJECTS, using the GET_EMP_PROJ procedure in place of a table:

```
EXEC SQL
DECLARE PROJECTS CURSOR FOR
SELECT PROJ_ID FROM GET_EMP_PROJ (:emp_no)
    ORDER BY PROJ_ID;
```

The following application C code with embedded SQL then uses the PROJECTS cursor to print project numbers to standard output:

```
EXEC SQL
OPEN PROJECTS

/* Print employee projects. */
while (SQLCODE == 0)
{
    EXEC SQL
        FETCH PROJECTS INTO :proj_id :nullind;
```
Using executable procedures

An executable procedure is called directly by an application, and often performs a task common to applications using the same database. Executable procedures can receive input parameters from the calling program, and can optionally return a single row to the calling program.

Input parameters pass to an executable procedure in a comma-delimited list following the procedure name.

Note Executable procedures cannot return multiple rows.

Executing a procedure

To execute a procedure in an application, use the following syntax:

```sql
EXEC SQL
EXECUTE PROCEDURE name [:param [[INDICATOR]:indicator]]
[[], :param [[INDICATOR]:indicator] ...]
[RETURNING_VALUES :param [[INDICATOR]:indicator]
[[], :param [[INDICATOR]:indicator]...]];
```

When an executable procedure uses input parameters, the parameters can be literal values (such as 7 or "Fred"), or host variables. If a procedure returns output parameters, host variables must be supplied in the RETURNING_VALUES clause to hold the values returned.

For example, the following statement demonstrates how the executable procedure, DEPT_BUDGET, is called with literal parameters:

```sql
EXEC SQL
EXECUTE PROCEDURE DEPT_BUDGET 100 RETURNING_VALUES :sumb;
```

The following statement also calls the same procedure using a host variable instead of a literal as the input parameter:

```sql
EXEC SQL
EXECUTE PROCEDURE DEPT_BUDGET :rdno RETURNING_VALUES :sumb;
```
Indicator variables

Both input parameters and return values can have associated indicator variables for tracking NULL values. You must use indicator variables to indicate unknown or NULL values of return parameters. The INDICATOR keyword is optional. An indicator variable that is less than zero indicates that the parameter is unknown or NULL. An indicator variable that is 0 indicates that the associated parameter contains a non-NULL value. For more information about indicator variables, see Chapter 6, “Working with Data.”

Executing a procedure in a DSQL application

To execute a stored procedure in a dynamic SQL (DSQL) application follow these steps:

1. Use a PREPARE statement to parse and prepare the procedure call for execution using the following syntax:

   ```sql
   EXEC SQL
   PREPARE sql_statement_name FROM : var  | '<statement>'; 
   ```

2. Set up an input XSQLDA using the following syntax:

   ```sql
   EXEC SQL
   DESCRIBE INPUT sql_statement_name INTO SQL DESCRIPTOR input_xsqllda;
   ```

3. Use DESCRIBE OUTPUT to set up an output XSQLDA using the following syntax:

   ```sql
   EXEC SQL
   DESCRIBE OUTPUT sql_statement_name INTO SQL DESCRIPTOR output_xsqllda;
   ```
   Setting up an output XSQLDA is only necessary for procedures that return values.

4. Execute the statement using the following syntax:

   ```sql
   EXEC SQL
   EXECUTE statement USING SQL DESCRIPTOR input_xsqllda INTO DESCRIPTOR output_xsqllda;
   ```

Input parameters to stored procedures can be passed as run-time values by substituting a question mark (?) for each value. For example, the following DSQL statements prepare and execute the ADD_EMP_PROJ procedure:

```c
strcpy(uquery, "EXECUTE PROCEDURE ADD_EMP_PROJ ?, ?");
....
EXEC SQL
PREPARE QUERY FROM : uquery;
```
EXEC SQL
  DESCRIBE INPUT QUERY INTO SQL DESCRIPTOR input_xsqllda;
EXEC SQL
  DESCRIBE OUTPUT QUERY INTO SQL DESCRIPTOR output_xsqllda;
EXEC SQL
  EXECUTE QUERY USING SQL DESCRIPTOR input_xsqllda INTO SQL DESCRIPTOR
    output_xsqllda;
...
Chapter 11 Working with Events

This chapter describes the InterBase event mechanism and how to write applications that register interest in and respond to events. The event mechanism enables applications to respond to actions and database changes made by other, concurrently running applications without the need for those applications to communicate directly with one another, and without incurring the expense of CPU time required for periodic polling to determine if an event has occurred.

Understanding the event mechanism

In InterBase, an event is a message passed by a trigger or a stored procedure to the InterBase event manager to announce the occurrence of a specified condition or action, usually a database change such as an INSERT, UPDATE, or DELETE. Events are passed by triggers or stored procedures only when the transaction under which they occur is committed.

The event manager maintains a list of events posted to it by triggers and stored procedures. It also maintains a list of applications that have registered an interest in events. Each time a new event is posted to it, the event manager notifies interested applications that the event has occurred.

Applications can respond to specific events that might be posted by a trigger or stored procedure by:
1. Indicating an interest in the events to the event manager.
2. Waiting for event notification.
3. Determining which event occurred (if an application is waiting for more than one event to occur).

The InterBase event mechanism, then, consists of three parts:

- A trigger or stored procedure that posts an event to the event manager.
- The event manager that maintains an event queue and notifies applications when an event occurs.
- An application that registers interest in the event and waits for it to occur.

A second application that uses the event-posting stored procedure (or that fires the trigger) causes the event manager to notify the waiting application so that it can resume processing.

**Signaling event occurrences**

A trigger or stored procedure must signal the occurrence of an event, usually a database change such as an INSERT, UPDATE, or DELETE, by using the POST_EVENT statement. POST_EVENT alerts the event manager to the occurrence of an event after a transaction is committed. At that time, the event manager passes the information to registered applications.

A trigger or stored procedure that posts an event is sometimes called an *event alerter*. For example, the following *isql* script creates a trigger that posts an event to the event manager whenever any application inserts data in a table:

```
SET TERM !! ;
CREATE TRIGGER POST_NEW_ORDER FOR SALES
  ACTIVE
  AFTER INSERT
  POSITION 0
AS
  BEGIN
    POST_EVENT 'new_order';
  END
!!
SET TERM ; !!
```

Event names are restricted to 15 characters in size.
Note POST_EVENT is a stored procedure and trigger language extension, available only within stored procedures and triggers.

For a complete discussion of writing a trigger or stored procedure as an event alerter, see the Data Definition Guide.

Registering interest in events

An application must register a request to be notified about a particular event with the InterBase event manager before waiting for the event to occur. To register interest in an event, use the EVENT INIT statement. EVENT INIT requires two arguments:

- An application-specific request handle to pass to the event manager.
- A list of events to be notified about, enclosed in parentheses.

The application-specific request handle is used by the application in a subsequent EVENT WAIT statement to indicate a readiness to receive event notification. The request handle is used by the event manager to determine where to send notification about particular events to wake up a sleeping application so that it can respond to them.

The list of event names in parentheses must match event names posted by triggers or stored procedures, or notification cannot occur.

To register interest in a single event, use the following EVENT INIT syntax:

```sql
EXEC SQL
  EVENT INIT request_name (event_name);
```

`event_name` can be up to 15 characters in size, and can be passed as a constant string in quotes, or as a host-language variable.

For example, the following application code creates a request named RESPOND_NEW that registers interest in the "new_order" event:

```sql
EXEC SQL
  EVENT INIT RESPOND_NEW ('new_order');
```

The next example illustrates how RESPOND_NEW might be initialized using a host-language variable, `myevent`, to specify the name of an event:

```sql
EXEC SQL
  EVENT INIT RESPOND_NEW (:myevent);
```

After an application registers interest in an event, it is not notified about an event until it first pauses execution with EVENT WAIT. For more information about waiting for events, see “Waiting for events with EVENT WAIT” on page 236.
Note As an alternative to registering interest in an event and waiting for the event to occur, applications can use an InterBase API call to register interest in an event, and identify an asynchronous trap (AST) function to receive event notification. This method enables an application to continue other processing instead of waiting for an event to occur. For more information about programming events with the InterBase API, see the API Guide.

Registering interest in multiple events

Often, an application may be interested in several different events even though it can only wait on a single request handle at a time. EVENT INIT enables an application to specify a list of event names in parentheses, using the following syntax:

EXEC SQL
  EVENT INIT request_name (event_name [event_name ...]);

Each event_name can be up to 15 characters in size, and should correspond to event names posted by triggers or stored procedures, or notification may never occur. For example, the following application code creates a request named RESPOND_MANY that registers interest in three events, “new_order,” “change_order,” and “cancel_order”:

EXEC SQL
  EVENT INIT RESPOND_MANY ('new_order', 'change_order', 'cancel_order');

Note An application can also register interest in multiple events by using a separate EVENT INIT statement with a unique request handle for a single event or groups of events, but it can only wait on one request handle at a time.

Waiting for events with EVENT WAIT

Even after an application registers interest in an event, it does not receive notification about that event. Before it can receive notification, it must use the EVENT WAIT statement to indicate its readiness to the event manager, and to suspend its processing until notification occurs.

To signal the event manager and suspend an application’s processing, use the following EVENT WAIT statement syntax:

EXEC SQL
  EVENT WAIT request_name;
request_name must be the name of a request handle declared in a previous EVENT INIT statement.

The following statements register interest in an event, and wait for event notification:

EXEC SQL
  EVENT INIT RESPOND_NEW ('new_order');
EXEC SQL
  EVENT WAIT RESPOND_NEW;

Once EVENT WAIT is executed, application processing stops until the event manager sends a notification message to the application.

Note An application can contain more than one EVENT WAIT statement, but all processing stops when the first statement is encountered. Each time processing restarts, it stops when it encounters the next EVENT WAIT statement.

If one event occurs while an application is processing another, the event manager sends notification the next time the application returns to a wait state.

Responding to events

When event notification occurs, a suspended application resumes normal processing at the next statement following EVENT WAIT.

If an application has registered interest in more than one event with a single EVENT INIT call, then the application must determine which event occurred by examining the event array, isc_event[]. The event array is automatically created for an application during preprocessing. Each element in the array corresponds to an event name passed as an argument to EVENT INIT. The value of each element is the number of times that event occurred since execution of the last EVENT WAIT statement with the same request handle.

In the following code, an application registers interest in three events, then suspends operation pending event notification:

EXEC SQL
  EVENT INIT RESPOND_MANY ('new_order', 'change_order', 'cancel_order');
EXEC SQL
  EVENT WAIT RESPOND_MANY;

When any of the “new_order,” “change_order,” or “cancel_order” events are posted and their controlling transactions commit, the event manager notifies the application and processing resumes. The following code illustrates how an application might test which event occurred:
for (i = 0; i < 3; i++)
{
    if (isc_$event[i] > 0)
    {
        /* this event occurred, so process it */
        ...
    }
}
All SQL applications should include mechanisms for trapping, responding to, and recovering from *run-time errors*, the errors that can occur when someone uses an application. This chapter describes both standard, portable SQL methods for handling errors, and additional error handling specific to InterBase.
Standard error handling

Every time an SQL statement is executed, it returns a status indicator in the SQLCODE variable, which is declared automatically for SQL programs during preprocessing with gpre. The following table summarizes possible SQLCODE values and their meanings:

<table>
<thead>
<tr>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Success</td>
</tr>
<tr>
<td>1–99</td>
<td>Warning or informational message</td>
</tr>
<tr>
<td>100</td>
<td>End of file (no more data)</td>
</tr>
<tr>
<td>&lt; 0</td>
<td>Error. Statement failed to complete</td>
</tr>
</tbody>
</table>

To trap and respond to run-time errors, SQLCODE should be checked after each SQL operation. There are three ways to examine SQLCODE and respond to errors:

- Use WHENEVER statements to automate checking SQLCODE and handle errors when they occur.
- Test SQLCODE directly after individual SQL statements.
- Use a judicious combination of WHENEVER statements and direct testing.

Each method has advantages and disadvantages, described fully in the remainder of this chapter.

WHENEVER statements

The WHENEVER statement enables all SQL errors to be handled with a minimum of coding. WHENEVER statements specify error-handling code that a program should execute when SQLCODE indicates errors, warnings, or end-of-file. The syntax of WHENEVER is:

```sql
EXEC SQL
WHENEVER {SQLERROR | SQLWARNING | NOT FOUND}
    {GOTO label | CONTINUE};
```

After WHENEVER appears in a program, all subsequent SQL statements automatically jump to the specified code location identified by `label` when the appropriate error or warning occurs.
Because they affect all subsequent statements, WHENEVER statements are usually embedded near the start of a program. For example, the first statement in the following C code's `main()` function is a WHENEVER that traps SQL errors:

```c
main()
{
  EXEC SQL
  WHENEVER SQLERROR GOTO ErrorExit;

  . . .
  Error Exit:
      if (SQLCODE)
      {
          print_error();
          EXEC SQL
              ROLLBACK;
          EXEC SQL
              DISCONNECT;
          exit(1);
      }

  . . .
  print_error()
  {
      printf("Database error, SQLCODE = %d\n", SQLCODE);
  }

Up to three WHENEVER statements can be active at any time:

- WHENEVER SQLERROR is activated when SQLCODE is less than zero, indicating that a statement failed.
- WHENEVER SQLWARNING is activated when SQLCODE contains a value from 1 to 99, inclusive, indicating that while a statement executed, there is some question about the way it succeeded.
- WHENEVER NOT FOUND is activated when SQLCODE is 100, indicating that end-of-file was reached during a FETCH or SELECT.

Omitting a statement for a particular condition means it is not trapped, even if it occurs. For example, if WHENEVER NOT FOUND is left out of a program, then when a FETCH or SELECT encounters the end-of-file, SQLCODE is set to 100, but program execution continues as if no error condition has occurred.

Error conditions also can be overlooked by using the CONTINUE statement inside a WHENEVER statement:
EXEC SQL
WHENEVER SQLWARNING
    CONTINUE;

This code traps SQLCODE warning values, but ignores them. Ordinarily, warnings should be investigated, not ignored.

IMPORTANT Use WHENEVER SQLERROR CONTINUE at the start of error-handling routines to disable error handling temporarily. Otherwise, there is a possibility of an infinite loop; should another error occur in the handler itself, the routine will call itself again.

SCOPE OF WHENEVER STATEMENTS
WHENEVER only affects all subsequent SQL statements in the module, or source code file, where it is defined. In programs with multiple source code files, each module must define its own WHENEVER statements.

CHANGING ERROR-HANDLING ROUTINES
To switch to another error-handling routine for a particular error condition, embed another WHENEVER statement in the program at the point where error handling should be changed. The new assignment overrides any previous assignment, and remains in effect until overridden itself. For example, the following program fragment sets an initial jump point for SQLERROR conditions to ErrorExit1, then resets it to ErrorExit2:

EXEC SQL
WHENEVER SQLERROR
    GOTO ErrorExit1;

. . .
EXEC SQL
WHENEVER SQLERROR
    GOTO ErrorExit2;

LIMITATIONS OF WHENEVER STATEMENTS
There are two limitations to WHENEVER. It:

- Traps errors indiscriminately. For example, WHENEVER SQLERROR traps both missing databases and data entry that violates a CHECK constraint, and jumps to a single error-handling routine. While a missing database is a severe error that may require action outside the context of the current program, invalid data entry may be the result of a typing mistake that could be fixed by reentering the data.
Does not easily enable a program to resume processing at the point where the error occurred. For example, a single WHENEVER SQLERROR can trap data entry that violates a CHECK constraint at several points in a program, but jumps to a single error-handling routine. It might be helpful to allow the user to reenter data in these cases, but the error routine cannot determine where to jump to resume program processing.

Error-handling routines can be very sophisticated. For example, in C or C++, a routine might use a large CASE statement to examine SQLCODE directly and respond differently to different values. Even so, creating a sophisticated routine that can resume processing at the point where an error occurred is difficult. To resume processing after error recovery, consider testing SQLCODE directly after each SQL statement, or consider using a combination of error-handling methods.

### Testing SQLCODE directly

A program can test SQLCODE directly after each SQL statement instead of relying on WHENEVER to trap and handle all errors. The main advantage to testing SQLCODE directly is that custom error-handling routines can be designed for particular situations.

For example, the following C code fragment checks if SQLCODE is not zero after a SELECT statement completes. If so, an error has occurred, so the statements inside the if clause are executed. These statements test SQLCODE for two specific values, –1, and 100, handling each differently. If SQLCODE is set to any other error value, a generic error message is displayed and the program is ended gracefully.

```sql
EXEC SQL
    SELECT CITY INTO :city FROM STATES
    WHERE STATE = :stat:statind;

if (SQLCODE)
{
    if (SQLCODE == -1)
        printf("too many records found\n");
    else if (SQLCODE == 100)
        printf("no records found\n");
    else
    {
        printf("Database error, SQLCODE = %d\n", SQLCODE);
        EXEC SQL
            ROLLBACK;
        EXEC SQL
            DISCONNECT;
```


exit(1);
}
}
printf("found city named %s\n", city);
EXEC SQL
  COMMIT;
EXEC SQL
  DISCONNECT;

The disadvantage to checking SQLCODE directly is that it requires many lines of extra code just to see if an error occurred. On the other hand, it enables errors to be handled with function calls, as the following C code illustrates:

EXEC SQL
  SELECT CITY INTO :city FROM STATES
    WHERE STATE = :stat:statind;

switch (SQLCODE)
{
  case 0:
    break; /* NO ERROR */
  case -1
    ErrorTooMany();
    break;
  case 100:
    ErrorNotFound();
    break;
  default:
    ErrorExit(); /* Handle all other errors */
    break;
}
...

Using function calls for error handling enables programs to resume execution if errors can be corrected.

Combining error-handling techniques

Error handling in many programs can benefit from combining WHENEVER with direct checking of SQLCODE. A program might include generic WHENEVER statements for handling most SQL error conditions, but for critical operations, WHENEVER statements might be temporarily overridden to enable direct checking of SQLCODE.
For example, the following C code:

- Sets up generic error handling with three WHENEVER statements.
- Overrides the WHENEVER SQLERROR statement to force program continuation using the CONTINUE clause.
- Checks SQLCODE directly.
- Overrides WHENEVER SQLERROR again to reset it.

```c
main()
{
    EXEC SQL
        WHENEVER SQLERROR GOTO ErrorExit; /* trap all errors */
    EXEC SQL
        WHENEVER SQLWARNING GOTO WarningExit; /* trap warnings */
    EXEC SQL
        WHENEVER NOT FOUND GOTO AllDone; /* trap end of file */
    . . .
    EXEC SQL
        WHENEVER SQLERROR CONTINUE; /* prevent trapping of errors */
    EXEC SQL
        SELECT CITY INTO :city FROM STATES
          WHERE STATE = :stat:statind;
    switch (SQLCODE)
    {
        case 0:
            break; /* NO ERROR */
        case -1
            ErrorTooMany();
            break;
        case 100:
            ErrorNotFound();
            break;
        default:
            ErrorExitFunction(); /* Handle all other errors */
            break;
    }
    EXEC SQL
        WHENEVER SQLERROR GOTO ErrorExit; /* reset to trap all errors */
    . . .
}
Guidelines for error handling

The following guidelines apply to all error-handling routines in a program.

USING SQL AND HOST-LANGUAGE STATEMENTS

All SQL statements and InterBase functions can be used in error-handling routines, except for CONNECT.

Any host-language statements and functions can appear in an error-handling routine without restriction.

IMPORTANT Use WHENEVER SQLERROR CONTINUE at the start of error-handling routines to disable error-handling temporarily. Otherwise, there is a possibility of an infinite loop; should another error occur in the handler itself, the routine will call itself again.

NESTING ERROR-HANDLING ROUTINES

Although error-handling routines can be nested or called recursively, this practice is not recommended unless the program preserves the original contents of SQLCODE and the InterBase error status array.

HANDLING UNEXPECTED AND UNRECOVERABLE ERRORS

Even if an error-handling routine catches and handles recoverable errors, it should always contain statements to handle unexpected or unrecoverable errors.

The following code handles unrecoverable errors:

```sql
... 
is_c_print_sqlerr(SQLCODE, isc_status);
EXEC SQL
  ROLLBACK;
EXEC SQL
  DISCONNECT;
exit(1);
```

PORTABILITY

For portability among different SQL implementations, SQL programs should limit error handling to WHENEVER statements or direct examination of SQLCODE values.

InterBase internal error recognition occurs at a finer level of granularity than SQLCODE representation permits. A single SQLCODE value can represent many different internal InterBase errors. Where portability is not an issue, it may be desirable to perform additional InterBase error handling. The remainder of this chapter explains how to use these additional features.
Additional InterBase error handling

The same SQLCODE value can be returned by multiple InterBase errors. For example, the SQLCODE value, -901, is generated in response to many different InterBase errors. When portability to other vendors’ SQL implementations is not required, SQL programs can sometimes examine the InterBase error status array, isc_status, for more specific error information.

isc_status is an array of twenty elements of type ISC_STATUS. It is declared automatically for programs when they are preprocessed with gpre. Two kinds of InterBase error information are reported in the status array:

- InterBase error message components.
- InterBase error numbers.

As long as the current SQLCODE value is not -1, 0, or 100, error-handling routines that examine the error status array can do any of the following:

- Display SQL and InterBase error messages.
- Capture SQL and InterBase error messages to a storage buffer for further manipulation.
- Trap for and respond to particular InterBase error codes.

The InterBase error status array is usually examined only after trapping errors with WHENEVER or testing SQLCODE directly.

Displaying error messages

If SQLCODE is less than -1, additional InterBase error information can be displayed using the InterBase isc_print_sqlerror() function inside an error-handling routine. During preprocessing with gpre, this function is automatically declared for InterBase applications.

isc_print_sqlerror() displays the SQLCODE value, a related SQL error message, and any InterBase error messages in the status array. It requires two parameters: SQLCODE, and a pointer to the error status array, isc_status.

For example, when an error occurs, the following code displays the value of SQLCODE, displays a corresponding SQL error message, then displays additional InterBase error message information if possible:

```sql
EXEC SQL
   SELECT CITY INTO :city FROM STATES
   WHERE STATE = :stat:statind;
if(SQLCODE)
```

...
{  
  isc_print_sqlerror(SQLCODE, isc_status);  
  EXEC SQL  
    ROLLBACK;  
  EXEC SQL  
    DISCONNECT ALL;  
  exit(1);  
}

IMPORTANT Some windowing systems do not encourage or permit direct screen writes. Do not use isc_print_sqlerror() when developing applications for these environments. Instead, use isc_sql_interprete() and isc_interprete() to capture messages to a buffer for display.

---

Capturing SQL error messages

Instead of displaying SQL error messages, an application can capture the text of those messages in a buffer by using isc_sql_interprete(). Capture messages in a buffer when applications:

- Run under windowing systems that do not permit direct writing to the screen.
- Store a record of all error messages in a log file.
- Manipulate or format error messages for display.

Given SQLCODE, a pointer to a storage buffer, and the maximum size of the buffer in bytes, isc_sql_interprete() builds an SQL error message string, and puts the formatted string in the buffer where it can be manipulated. A buffer size of 256 bytes is large enough to hold any SQL error message.

For example, the following code stores an SQL error message in err_buf, then writes err_buf to a log file:

```c
char err_buf[256]; /* error message buffer for isc_sql_interprete() */  
FILE *efile=NULL; /* code fragment assumes pointer to an open file */
EXEC SQL
  SELECT CITY INTO :city FROM STATES  
  WHERE STATE = :stat:statind;
if (SQLCODE)
  {
    isc_sql_interprete(SQLCODE, err_buf, sizeof(err_buf));
```
if (efile == NULL) efile = fopen("errors", "w");
fprintf(efile, "%s\n", err_buf); /* write buffer to log file */
EXEC SQL
    ROLLBACK; /* undo database changes */
EXEC SQL
    DISCONNECT ALL; /* close open databases */
exit(1); /* exit with error flag set */

isc_sql_interprete() retrieves and formats a single message corresponding to a given SQLCODE. When SQLCODE is less than –1, more specific InterBase error information is available. It, too, can be retrieved, formatted, and stored in a buffer by using the isc_interprete() function.

Capturing InterBase error messages

The text of InterBase error messages can be captured in a buffer by using isc_interprete(). Capture messages in a buffer when applications:

- Run under windowing systems that do not permit direct writing to the screen.
- Store a record of all error messages in a log file.
- Manipulate or format error messages for display.

IMPORTANT isc_interprete() should not be used unless SQLCODE is less than –1 because the contents of isc_status may not contain reliable error information in these cases.

Given both the location of a storage buffer previously allocated by the program, and a pointer to the start of the status array, isc_interprete() builds an error message string from the information in the status array, and puts the formatted string in the buffer where it can be manipulated. It also advances the status array pointer to the start of the next cluster of available error information.

isc_interprete() retrieves and formats a single error message each time it is called. When an error occurs in an InterBase program, however, the status array may contain more than one error message. To retrieve all relevant error messages, error-handling routines should repeatedly call isc_interprete() until it returns no more messages.

Because isc_interprete() modifies the pointer to the status array that it receives, do not pass isc_status directly to it. Instead, declare a pointer to isc_status, then pass the pointer to isc_interprete().
The following C code fragment illustrates how InterBase error messages can be captured to a log file, and demonstrates the proper declaration of a string buffer and pointer to \texttt{isc\_status}. It assumes the log file is properly declared and opened \emph{before} control is passed to the error-handling routine. It also demonstrates how to set the pointer to the start of the status array in the error-handling routine \emph{before} \texttt{isc\_interpret()} is first called.

```c
#include "ibase.h";
...
main()
{
char msg[512];
ISC_STATUS *vector;
FILE *efile; /* code fragment assumes pointer to an open file */
...
if (SQLCODE < -1)
  ErrorExit();
}
...
ErrorExit()
{
  vector = isc_status; /* (re)set to start of status vector */
  isc_interpret(msg, &vector); /* retrieve first message */
  fprintf(efile, "\%s\n", msg); /* write buffer to log file */
  msg[0] = '-'; /* append leading hyphen to secondary messages */
  while (isc_interpret(msg + 1, &vector)) /* more?*/
    fprintf(efile, "\%s\n", msg); /* if so, write it to log */
  fclose(efile); /* close log prior to quitting program */
  EXEC SQL
    ROLLBACK;
  EXEC SQL
    DISCONNECT ALL;
  exit(1); /* quit program with an 'abnormal termination' code */
}
...

In this example, the error-handling routine performs the following tasks:

- Sets the error array pointer to the starting address of the status vector, \texttt{isc\_status}.
- Calls \texttt{isc\_interpret()} a single time to retrieve the first error message from the status vector.
- Writes the first message to a log file.
- Makes repeated calls to `isc_interprete()` within a WHILE loop to retrieve any additional messages. If additional messages are retrieved, they are also written to the log file.
- Rolls back the transaction.
- Closes the database and releases system resources.

### Handling InterBase error codes

Whenever SQLCODE is less than −1, the error status array, `isc_status`, may contain detailed error information specific to InterBase, including *error codes*, numbers that uniquely identify each error. With care, error-handling routines can trap for and respond to specific codes.

To trap and handle InterBase error codes in an error-handling routine, follow these steps:

1. Check SQLCODE to be sure it is less than −1.
2. Check that the first element of the status array is set to `isc_arg_gds`, indicating that an InterBase error code is available. In C programs, the first element of the status array is `isc_status[0]`.
   
   Do *not* attempt to handle errors reported in the status array if the first status array element contains a value other than 1.
3. If SQLCODE is less than −1 and the first element in `isc_status` is set to `isc_arg_gds`, use the actual InterBase error code in the second element of `isc_status` to branch to an appropriate routine for that error.

**Tip**

InterBase error codes are mapped to mnemonic definitions (for example, `isc_arg_gds`) that can be used in code to make it easier to read, understand, and maintain. Definitions for all InterBase error codes can be found in the `ibase.h` file.

The following C code fragment illustrates an error-handling routine that:

- Displays error messages with `isc_print_sqlerror()`.
- Illustrates how to parse for and handle six specific InterBase errors which might be corrected upon roll back, data entry, and retry.
- Uses mnemonic definitions for InterBase error numbers.

```c
. . .
int c, jval, retry_flag = 0;
jmp_buf jumper;
. . .
```
main()
{
   . . .
   jval = setjmp(jumper);
   if (retry_flag)
       ROLLBACK;
   . . .
}

int ErrorHandler(void)
{
   retry_flag = 0; /* reset to 0, no retry */
   isc_print_sqlerror(SQLCODE, isc_status); /* display errors */
   if (SQLCODE < -1)
   {
      if (isc_status[0] == isc_arg_gds)
      {
         switch (isc_status[1])
         {
            case isc_convert_error:
            case isc_deadlock:
            case isc_integ_fail:
            case isc_lock_conflict:
            case isc_no_dup:
            case isc_not_valid:
               printf("\n Do you want to try again? (Y/N)");
               c = getchar();
               if (c == 'Y' || c == 'y')
               {
                  retry_flag = 1; /* set flag to retry */
                  longjmp(jumper, 1);
               }
               break;
            case isc_end_arg: /* there really isn’t an error */
               retry_flag = 1; /* set flag to retry */
               longjmp(jumper, 1);
               break;
            default: /* we can’t handle everything, so abort */
               break;
         }
      }
   }
   EXEC SQL
ROLLBACK;
EXEC SQL
    DISCONNECT ALL;
exit(1);
This chapter describes how to write dynamic SQL applications, applications that elicit or build SQL statements for execution at run time.

In many database applications, the programmer specifies exactly which SQL statements to execute against a particular database. When the application is compiled, these statements become fixed. In some database applications, it is useful to build and execute statements from text string fragments or from strings elicited from the user at run time. These applications require the capability to create and execute SQL statements dynamically at run time. Dynamic SQL (DSQL) provides this capability. For example, the InterBase isql utility is a DSQL application.

Overview of the DSQL programming process

Building and executing DSQL statements involves the following general steps:

- Embedding SQL statements that support DSQL processing in an application.
- Using host-language facilities, such as datatypes and macros, to provide input and output areas for passing statements and parameters at run time.
- Programming methods that use these statements and facilities to process SQL statements at run time.

These steps are described in detail throughout this chapter.
DSQL limitations

Although DSQL offers many advantages, it also has the following limitations:

- Access to one database at a time.
- Dynamic transaction processing is not permitted; all named transactions must be declared at compile time.
- Dynamic access to Blob and array data is not supported; Blob and array data can be accessed, but only through standard, statically processed SQL statements, or through low-level API calls.
- Database creation is restricted to CREATE DATABASE statements executed within the context of EXECUTE IMMEDIATE.

For more information about handling transactions in DSQL applications, see “Handling transactions” on page 257. For more information about working with Blob data in DSQL, see “Processing Blob data” on page 259. For more information about handling array data in DSQL, see “Processing array data” on page 259. For more information about dynamic creation of databases, see “Creating a database” on page 258.

Accessing databases

Using standard SQL syntax, a DSQL application can only use one database handle per source file module, and can, therefore, only be connected to a single database at a time. Database handles must be declared and initialized when an application is preprocessed with gpre. For example, the following code creates a single handle, db1, and initializes it to zero:

```c
#include "ibase.h"
isc_db_handle db1;
... db1 = 0L;
```

After a database handle is declared and initialized, it can be assigned dynamically to a database at run time as follows:

```c
char dbname[129];
... prompt_user("Name of database to open: ");
gets(dbname);
EXEC SQL
    SET DATABASE db1 = :dbname;
EXEC SQL
```
CONNECT db1;

The database accessed by DSQL statements is always the last database handle mentioned in a SET DATABASE command. A database handle can be used to connect to different databases as long as a previously connected database is first disconnected with DISCONNECT. DISCONNECT automatically sets database handles to NULL. The following statements disconnect from a database, zero the database handle, and connect to a new database:
EXEC SQL
  DISCONNECT db1;
EXEC SQL
  SET DATABASE db1 = 'employee.gdb';
EXEC SQL
  CONNECT db1;

To access more than one database using DSQL, create a separate source file module for each database, and use low-level API calls to attach to the databases and access data. For more information about accessing databases with API calls, see the API Guide. For more information about SQL database statements, see Chapter 3, “Working with Databases.”

Handling transactions

InterBase requires that all transaction names be declared when an application is preprocessed with gpre. Once fixed at precompile time, transaction handles cannot be changed at run time, nor can new handles be declared dynamically at run time.

SQL statements such as PREPARE, DESCRIBE, EXECUTE, and EXECUTE IMMEDIATE, can be coded at precompile time to include an optional TRANSACTION clause specifying which transaction controls statement execution. The following code declares, initializes, and uses a transaction handle in a statement that processes a run-time DSQL statement:

```
#include "ibase.h"
isc_tr_handle t1;
  . . .
t1 = 0L;
EXEC SQL
  SET TRANSACTION NAME t1;
EXEC SQL
  PREPARE TRANSACTION t1 Q FROM :sql_buf;
```
DSQL statements that are processed with PREPARE, DESCRIBE, EXECUTE, and EXECUTE IMMEDIATE cannot use a TRANSACTION clause, even if it is permitted in standard, embedded SQL.

The SET TRANSACTION statement cannot be prepared, but it can be processed with EXECUTE IMMEDIATE if:

1. Previous transactions are first committed or rolled back.
2. The transaction handle is set to NULL.

For example, the following statements commit the previous default transaction, then start a new one with EXECUTE IMMEDIATE:

```sql
EXEC SQL
    COMMIT;
/* set default transaction name to NULL */
gds__trans = NULL;
EXEC SQL
    EXECUTE IMMEDIATE 'SET TRANSACTION READ ONLY';
```

---

### Creating a database

To create a new database in a DSQL application:

1. Disconnect from any currently attached databases. Disconnecting from a database automatically sets its database handle to NULL.
2. Build the CREATE DATABASE statement to process.
3. Execute the statement with EXECUTE IMMEDIATE.

For example, the following statements disconnect from any currently connected databases, and create a new database. Any existing database handles are set to NULL, so that they can be used to connect to the new database in future DSQL statements.

```sql
char *str = "CREATE DATABASE "new_emp.gdb";"
... 
EXEC SQL
    DISCONNECT ALL;
EXEC SQL
    EXECUTE IMMEDIATE :str;
```
Processing Blob data

DSQL does not directly support Blob processing. Blob cursors are not supported in DSQL. DSQL applications can use API calls to process Blob data. For more information about Blob API calls, see the API Guide.

Processing array data

DSQL does not directly support array processing. DSQL applications can use API calls to process array data. For more information about array API calls, see the API Guide.

Writing a DSQL application

Write a DSQL application when any of the following are not known until run time:

- The text of the SQL statement
- The number of host variables
- The datatypes of host variables
- References to database objects

Writing a DSQL application is usually more complex than programming with regular SQL because for most DSQL operations, the application needs explicitly to allocate and process an extended SQL descriptor area (XSQLDA) data structure to pass data to and from the database.

To use DSQL to process an SQL statement, follow these basic steps:

1. Determine if DSQL can process the SQL statement.
2. Represent the SQL statement as a character string in the application.
3. If necessary, allocate one or more XSQLDAs for input parameters and return values.
4. Use an appropriate DSQL programming method to process the SQL statement.
SQL statements that DSQL can process

DSQL can process most but not all SQL statements. The following table lists SQL statement that are available to DSQL:

<table>
<thead>
<tr>
<th>SQL Statement</th>
<th>DSQL Available Statements</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALTER DATABASE</td>
<td>DECLARE FILTER REVOKE SET GENERATOR UPDATE</td>
</tr>
<tr>
<td>ALTER DOMAIN</td>
<td>DELETE DBF DROP DATABASE</td>
</tr>
<tr>
<td>ALTER EXCEPTION</td>
<td>DROP DATABASE DROP DOMAIN</td>
</tr>
<tr>
<td>ALTER INDEX</td>
<td>DROP DATABASE</td>
</tr>
<tr>
<td>ALTER PROCEDURE</td>
<td>DROP DATABASE DROP EXCEPTION</td>
</tr>
<tr>
<td>ALTER TABLE</td>
<td>DROP DATABASE DROP EXTERNAL FUNCTION</td>
</tr>
<tr>
<td>ALTER TRIGGER</td>
<td>DROP DATABASE DROP FILTER</td>
</tr>
<tr>
<td>COMMIT</td>
<td>DROP DATABASE DROP INDEX</td>
</tr>
<tr>
<td>CONNECT</td>
<td>DROP PROCEDURE</td>
</tr>
<tr>
<td>CREATE DATABASE</td>
<td>DROP ROLE</td>
</tr>
<tr>
<td>CREATE DOMAIN</td>
<td>DROP SHADOW</td>
</tr>
<tr>
<td>CREATE EXCEPTION</td>
<td>DROP TABLE</td>
</tr>
<tr>
<td>CREATE GENERATOR</td>
<td>DROP TRIGGER</td>
</tr>
<tr>
<td>CREATE INDEX</td>
<td>DROP VIEW</td>
</tr>
<tr>
<td>CREATE PROCEDURE</td>
<td>EXECUTE PROCEDURE</td>
</tr>
<tr>
<td>CREATE ROLE</td>
<td>GRANT</td>
</tr>
<tr>
<td>CREATE SHADOW</td>
<td>INSERT</td>
</tr>
<tr>
<td>CREATE TABLE</td>
<td>INSERT CURSOR (BLOB)</td>
</tr>
<tr>
<td>CREATE TRIGGER</td>
<td>REVOKE</td>
</tr>
<tr>
<td>CREATE VIEW</td>
<td>ROLLBACK</td>
</tr>
<tr>
<td>DECLARE EXTERNAL FUNCTION</td>
<td></td>
</tr>
</tbody>
</table>

The following ESQL statements cannot be processed by DSQL: CLOSE, DECLARE, CURSOR, DESCRIBE, EXECUTE, EXECUTE IMMEDIATE, FETCH, OPEN, PREPARE.

The following ISQL commands cannot be processed by DSQL: BLOBDUMP, EDIT, EXIT, HELP, INPUT, OUTPUT, QUIT, SET, SET AUTODDL, SET BLOBDISPLAY, SET COUNT, SET ECHO, SET LIST, SET NAMES, SET PLAN, SET STATS, SET TERM, SET TIME, SHELL, SHOW CHECK, SHOW DATABASE, SHOW DOMAINS, SHOW EXCEPTIONS, SHOW FILTERS, SHOW FUNCTIONS, SHOW GENERATORS, SHOW GRANT, SHOW INDEX, SHOW PROCEDURES, SHOW SYSTEM, SHOW TABLES, SHOW TRIGGERS, SHOW VERSION, SHOW VIEWS.
SQL character strings

Within a DSQL application, an SQL statement can come from different sources. It can come directly from a user who enters a statement at a prompt, as does isql. Or it can be generated by the application in response to user interaction. Whatever the source of the SQL statement it must be represented as an SQL statement string, a character string that is passed to DSQL for processing.

Because SQL statement strings are C character strings that are processed directly by DSQL, they cannot begin with the EXEC SQL prefix or end with a semicolon (;). The semicolon is, of course, the appropriate terminator for the C string declaration itself. For example, the following host-language variable declaration is a valid SQL statement string:

```c
char *str = "DELETE FROM CUSTOMER WHERE CUST_NO = 256";
```

Value parameters in statement strings

SQL statement strings often include value parameters, expressions that evaluate to a single numeric or character value. Parameters can be used anywhere in statement strings where SQL expects a value that is not the name of a database object.

A value parameter in a statement string can be passed as a constant, or passed as a placeholder at run time. For example, the following statement string passes 256 as a constant:

```c
char *str = "DELETE FROM CUSTOMER WHERE CUST_NO = 256";
```

It is also possible to build strings at run time from a combination of constants. This method is useful for statements where the variable is not a true constant, or it is a table or column name, and where the statement is executed only once in the application.

To pass a parameter as a placeholder, the value is passed as a question mark (?) embedded within the statement string:

```c
char *str = "DELETE FROM CUSTOMER WHERE CUST_NO = ?";
```

When DSQL processes a statement containing a placeholder, it replaces the question mark with a value supplied in the XSQLDA. Use placeholders in statements that are prepared once, but executed many times with different parameter values.

Replaceable value parameters are often used to supply values in WHERE clause comparisons and in the UPDATE statement SET clause.
Understanding the XSQLDA

All DSQL applications must declare one or more extended SQL descriptor areas (XSQLDAs). The XSQLDA structure definition can be found in the `ibase.h` header file in the InterBase include directory. Applications declare instances of the XSQLDA for use.

The XSQLDA is a host-language data structure that DSQL uses to transport data to or from a database when processing an SQL statement string. There are two types of XSQLDAs: input descriptors and output descriptors. Both input and output descriptors are implemented using the XSQLDA structure.

One field in the XSQLDA, the XSQLVAR, is especially important, because one XSQLVAR must be defined for each input parameter or column returned. Like the XSQLDA, the XSQLVAR is a structure defined in `ibase.h` in the InterBase include directory.

Applications do not declare instances of the XSQLVAR ahead of time, but must, instead, dynamically allocate storage for the proper number of XSQLVAR structures required for each DSQL statement before it is executed, then deallocate it, as appropriate, after statement execution.

The following figure illustrates the relationship between the XSQLDA and the XSQLVAR:
An input XSQLDA consists of a single XSQLDA structure, and one XSQLVAR structure for each input parameter. An output XSQLDA also consists of one XSQLDA structure and one XSQLVAR structure for each data item returned by the statement. An XSQLDA and its associated XSQLVAR structures are allocated as a single block of contiguous memory.
The PREPARE and DESCRIBE statements can be used to determine the proper number of XSQLVAR structures to allocate, and the XSQLDA_LENGTH macro can be used to allocate the proper amount of space. For more information about the XSQLDA_LENGTH macro, see “Using the XSQLDA_LENGTH macro” on page 267.

### XSQLDA field descriptions

The following table describes the fields that comprise the XSQLDA structure:

<table>
<thead>
<tr>
<th>Field definition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>short version</td>
<td>Indicates the version of the XSQLDA structure. Set by an application. The current version is defined in ibase.h as SQLDA_VERSION1.</td>
</tr>
<tr>
<td>ISC_LONG sqldabc</td>
<td>Reserved for future use.</td>
</tr>
<tr>
<td>short sqln</td>
<td>Indicates the number of elements in the sqlvar array. Set by the application. Whenever the application allocates storage for a descriptor, it should set this field.</td>
</tr>
<tr>
<td>short sqld</td>
<td>Indicates the number of parameters (for an input XSQLDA), or the number of select-list items (for an output XSQLDA). Set by InterBase during a DESCRIBE or PREPARE. For an input descriptor, an sqld of 0 indicates that the SQL statement has no parameters. For an output descriptor, an sqld of 0 indicates that the SQL statement is not a SELECT statement.</td>
</tr>
<tr>
<td>XSQLVAR sqlvar</td>
<td>The array of XSQLVAR structures. The number of elements in the array is specified in the sqln field.</td>
</tr>
</tbody>
</table>

TABLE 13.1 XSQLDA field descriptions
The following table describes the fields that comprise the XSQLVAR structure:

<table>
<thead>
<tr>
<th>Field definition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>short sqltype</td>
<td>Indicates the SQL datatype of parameters or select-list items. Set by InterBase during PREPARE or DESCRIBE.</td>
</tr>
<tr>
<td>short sqlscale</td>
<td>Provides scale, specified as a negative number, for exact numeric datatypes (DECIMAL, NUMERIC). Set by InterBase during PREPARE or DESCRIBE.</td>
</tr>
<tr>
<td>short sqlsubtype</td>
<td>Specifies the subtype for Blob data. Set by InterBase during PREPARE or DESCRIBE.</td>
</tr>
<tr>
<td>short sqllen</td>
<td>Indicates the maximum size, in bytes, of data in the sqldata field. Set by InterBase during PREPARE or DESCRIBE.</td>
</tr>
<tr>
<td>char *sqldata</td>
<td>For input descriptors, specifies either the address of a select-list item or a parameter. Set by the application. For output descriptors, contains a value for a select-list item. Set by InterBase.</td>
</tr>
<tr>
<td>short *sqlind</td>
<td>On input, specifies the address of an indicator variable. Set by an application. On output, specifies the address of column indicator value for a select-list item following a FETCH. A value of 0 indicates that the column is not NULL; a value of –1 indicates the column is NULL. Set by InterBase.</td>
</tr>
<tr>
<td>short sqlname_length</td>
<td>Specifies the length, in bytes, of the data in field, sqservername. Set by InterBase during DESCRIBE OUTPUT.</td>
</tr>
<tr>
<td>char sqname[32]</td>
<td>Contains the name of the column. Not null (\0) terminated. Set by InterBase during DESCRIBE OUTPUT.</td>
</tr>
<tr>
<td>short relname_length</td>
<td>Specifies the length, in bytes, of the data in field, relname. Set by InterBase during DESCRIBE OUTPUT.</td>
</tr>
</tbody>
</table>
Input descriptors process SQL statement strings that contain parameters. Before an application can execute a statement with parameters, it must supply values for them. The application indicates the number of parameters passed in the XSQLDA sqld field, then describes each parameter in a separate XSQLVAR structure. For example, the following statement string contains two parameters, so an application must set sqld to 2, and describe each parameter:

```c
char *str = "UPDATE DEPARTMENT SET BUDGET = ? WHERE LOCATION = ?";
```

When the statement is executed, the first XSQLVAR supplies information about the BUDGET value, and the second XSQLVAR supplies the LOCATION value.

For more information about using input descriptors, see “DSQL programming methods” on page 273.

### Output descriptors

Output descriptors return values from an executed query to an application. The sqld field of the XSQLDA indicates how many values were returned. Each value is stored in a separate XSQLVAR structure. The XSQLDA sqld field points to the first of these XSQLVAR structures. The following statement string requires an output descriptor:

```c
char *str = "SELECT * FROM CUSTOMER WHERE CUST_NO > 100";
```
For information about retrieving information from an output descriptor, see "DSQL programming methods" on page 273.

**Using the XSQLDA_LENGTH macro**

The `ibase.h` header file defines a macro, XSQLDA_LENGTH, to calculate the number of bytes that must be allocated for an input or output XSQLDA. XSQLDA_LENGTH is defined as follows:

```
#define XSQLDA_LENGTH (n) (sizeof (XSQLDA) + (n - 1) * sizeof(XSQLVAR))
```

$n$ is the number of parameters in a statement string, or the number of select-list items returned from a query. For example, the following C statement uses the XSQLDA_LENGTH macro to specify how much memory to allocate for an XSQLDA with 5 parameters or return items:

```
XSQLDA *my_xsqlda;
...
my_xsqlda = (XSQLDA *) malloc(XSQLDA_LENGTH(5));
...
```

For more information about using the XSQLDA_LENGTH macro, see "DSQL programming methods" on page 273.
## SQL datatype macro constants

InterBase defines a set of macro constants to represent SQL datatypes and NULL status information in an XSQLVAR. An application should use these macro constants to specify the datatype of parameters and to determine the datatypes of select-list items in an SQL statement. The following table lists each SQL datatype, its corresponding macro constant expression, C datatype or InterBase typedef, and whether or not the `sqlind` field is used to indicate a parameter or variable that contains NULL or unknown data:

<table>
<thead>
<tr>
<th>SQL datatype</th>
<th>Macro expression</th>
<th>C datatype or typedef</th>
<th>sqlind used?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Array</td>
<td>SQL_ARRAY</td>
<td>ISC_QUAD</td>
<td>No</td>
</tr>
<tr>
<td>Array</td>
<td>SQL_ARRAY + 1</td>
<td>ISC_QUAD</td>
<td>Yes</td>
</tr>
<tr>
<td>Blob</td>
<td>SQL_BLOB</td>
<td>ISC_QUAD</td>
<td>No</td>
</tr>
<tr>
<td>Blob</td>
<td>SQL_BLOB + 1</td>
<td>ISC_QUAD</td>
<td>Yes</td>
</tr>
<tr>
<td>CHAR</td>
<td>SQL_TEXT</td>
<td>char[ ]</td>
<td>No</td>
</tr>
<tr>
<td>CHAR</td>
<td>SQL_TEXT + 1</td>
<td>char[ ]</td>
<td>Yes</td>
</tr>
<tr>
<td>DATE</td>
<td>SQL_DATE</td>
<td>ISC_DATE</td>
<td>No</td>
</tr>
<tr>
<td>DATE</td>
<td>SQL_DATE + 1</td>
<td>ISC_DATE</td>
<td>Yes</td>
</tr>
<tr>
<td>DECIMAL</td>
<td>SQL_SHORT, SQL_LONG, SQL_DOUBLE, or SQL_INT64</td>
<td>int, long, double, or ISC_INT64</td>
<td>No</td>
</tr>
<tr>
<td>DECIMAL</td>
<td>SQL_SHORT+1, SQL_LONG+1, SQL_DOUBLE+1, or SQL_INT64+1</td>
<td>int, long, double, or ISC_INT64</td>
<td>Yes</td>
</tr>
<tr>
<td>DOUBLE PRECISION</td>
<td>SQL_DOUBLE</td>
<td>double</td>
<td>No</td>
</tr>
<tr>
<td>DOUBLE PRECISION</td>
<td>SQL_DOUBLE + 1</td>
<td>double</td>
<td>Yes</td>
</tr>
<tr>
<td>INTEGER</td>
<td>SQL_LONG</td>
<td>long</td>
<td>No</td>
</tr>
<tr>
<td>INTEGER</td>
<td>SQL_LONG + 1</td>
<td>long</td>
<td>Yes</td>
</tr>
<tr>
<td>FLOAT</td>
<td>SQL_FLOAT</td>
<td>float</td>
<td>No</td>
</tr>
<tr>
<td>FLOAT</td>
<td>SQL_FLOAT + 1</td>
<td>float</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**TABLE 13.3** SQL datatypes, macro expressions, and C datatypes
DECIMAL and NUMERIC datatypes are stored internally as SMALLINT, INTEGER, DOUBLE PRECISION, or 64-bit integer datatypes. To specify the correct macro expression to provide for a DECIMAL or NUMERIC column, use `isql` to examine the column definition in the table to see how InterBase is storing column data, then choose a corresponding macro expression.

The datatype information for a parameter or select-list item is contained in the `sqltype` field of the XSQLVAR structure. The value contained in the `sqltype` field provides two pieces of information:

- The datatype of the parameter or select-list item.
- Whether `sqlind` is used to indicate NULL values. If `sqlind` is used, its value specifies whether the parameter or select-list item is NULL (−1), or not NULL (0).

### TABLE 13.3

<table>
<thead>
<tr>
<th>SQL datatype</th>
<th>Macro expression</th>
<th>C datatype or typedef</th>
<th><code>sqlind</code> used?</th>
</tr>
</thead>
<tbody>
<tr>
<td>NUMERIC</td>
<td>SQL_SHORT, SQL_LONG,</td>
<td>int, long, double, or ISC_INT64</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>SQL_DOUBLE, or SQL_INT64</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NUMERIC</td>
<td>SQL_SHORT + 1, SQL_LONG + 1,</td>
<td>int, long, double, or ISC_INT64</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>SQL_DOUBLE + 1, or SQL_INT64 + 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMALLINT</td>
<td>SQL_SHORT</td>
<td>short</td>
<td>No</td>
</tr>
<tr>
<td>SMALLINT</td>
<td>SQL_SHORT + 1</td>
<td>short</td>
<td>Yes</td>
</tr>
<tr>
<td>TIME</td>
<td>SQL_TIME</td>
<td>ISC_TIME</td>
<td>No</td>
</tr>
<tr>
<td>TIME</td>
<td>SQL_TIME + 1</td>
<td>ISC_TIME</td>
<td>Yes</td>
</tr>
<tr>
<td>TIMESTAMP</td>
<td>SQL_TIMESTAMP</td>
<td>ISC_TIMESTAMP</td>
<td>No</td>
</tr>
<tr>
<td>TIMESTAMP</td>
<td>SQL_TIMESTAMP + 1</td>
<td>ISC_TIMESTAMP</td>
<td>Yes</td>
</tr>
<tr>
<td>VARCHAR</td>
<td>SQL_VARYING</td>
<td>First 2 bytes: short containing the length of the character string. Remaining bytes: char[]</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VARCHAR</td>
<td>SQL_VARYING + 1</td>
<td>First 2 bytes: short containing the length of the character string. Remaining bytes: char[]</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Note**
For example, if the sqltype field equals SQL_TEXT, the parameter or select-list item is a CHAR that does not use sqlind to check for a NULL value (because, in theory, NULL values are not allowed for it). If sqltype equals SQL_TEXT + 1, then sqlind can be checked to see if the parameter or select-list item is NULL.

**Tip** The C language expression, sqltype & 1, provides a useful test of whether a parameter or select-list item can contain a NULL. The expression evaluates to 0 if the parameter or select-list item cannot contain a NULL, and 1 if the parameter or select-list item can contain a NULL. The following code fragment demonstrates how to use the expression:

```c
if (sqltype & 1 == 0)
{
  /* parameter or select-list item that CANNOT contain a NULL */
}
else
{
  /* parameter or select-list item CAN contain a NULL */
}
```

By default, both PREPARE INTO and DESCRIBE return a macro expression of type + 1, so the sqlind should always be examined for NULL values with these statements.

---

**Handling varying string datatypes**

VARCHAR, CHARACTER VARYING, and NCHAR VARYING datatypes require careful handling in DSQL. The first two bytes of these datatypes contain string length information, while the remainder of the data contains the actual bytes of string data to process.

To avoid having to write code to extract and process variable-length strings in an application, it is possible to force these datatypes to fixed length using SQL macro expressions. For more information about forcing variable-length data to fixed length for processing, see “**Coercing datatypes**” on page 271.

Applications can, instead, detect and process variable-length data directly. To do so, they must extract the first two bytes from the string to determine the byte-length of the string itself, then read the string, byte-by-byte, into a null-terminated buffer.
**NUMERIC and DECIMAL datatypes**

DECIMAL and NUMERIC datatypes are stored internally as SMALLINT, INTEGER, DOUBLE PRECISION, or 64-bit integer datatypes, depending on the precision and scale defined for a column definition that uses these types. To determine how a DECIMAL or NUMERIC value is actually stored in the database, use ISQL to examine the column definition in the table. If NUMERIC is reported, then data is actually being stored as a 64-bit integer.

When a DECIMAL or NUMERIC value is stored as a SMALLINT or INTEGER, the value is stored as a whole number. During retrieval in DSQL, the SQLSCALE field of the XSQLVAR is set to a negative number that indicates the factor of ten by which the whole number (returned in SQLDATA), must be divided in order to produce the correct NUMERIC or DECIMAL value with its fractional part. If SQLSCALE is −1, then the number must be divided by 10, if it is −2, then the number must be divided by 100, −3 by 1,000, and so forth.

**Coercing datatypes**

Sometimes when processing DSQL input parameters and select-list items, it is desirable or necessary to translate one datatype to another. This process is referred to as **datatype coercion**. For example, datatype coercion is often used when parameters or select-list items are of type VARCHAR. The first two bytes of VARCHAR data contain string length information, while the remainder of the data is the string to process. By coercing the data from SQL_VARYING to SQL_TEXT, data processing can be simplified. Coercion can only be from one compatible datatype to another. For example, SQL_VARYING to SQL_TEXT, or SQL_SHORT to SQL_LONG.

- **Coercing character datatypes**

To coerce SQL_VARYING datatypes to SQL_TEXT datatypes, change the SQLTYPE field in the parameter’s or select-list item’s XSQLVAR structure to the desired SQL macro datatype constant. For example, the following statement assumes that var is a pointer to an XSQLVAR structure, and that it contains an SQL_VARYING datatype to convert to SQL_TEXT:

```
var->sqltype = SQL_TEXT;
```

After coercing a character datatype, provide proper storage space for it. The XSQLVAR field, SQLLEN, contains information about the size of the uncoerced data. Set the XSQLVAR SQLDATA field to the address of the data.
Coercing numeric datatypes

To coerce one numeric datatype to another, change the sqltype field in the parameter’s or select-list item’s XSQLVAR structure to the desired SQL macro datatype constant. For example, the following statement assumes that var is a pointer to an XSQLVAR structure, and that it contains an SQL_SHORT datatype to convert to SQL_LONG:

\[
\text{var->sqltype} = \text{SQL_LONG};
\]

IMPORTANT: Do not coerce a larger datatype to a smaller one. Data can be lost in such a translation.

Setting a NULL indicator

If a parameter or select-list item can contain a NULL value, the sqlind field is used to indicate its NULL status. Appropriate storage space must be allocated for sqlind before values can be stored there.

On insertion, set sqlind to –1 to indicate that NULL values are legal. Otherwise set sqlind to 0.

On selection, an sqlind of –1 indicates a field contains a NULL value. Other values indicate a field contains non-NULL data.

Aligning numerical data

Ordinarily, when a variable with a numeric datatype is created, the compiler will ensure that the variable is stored at a properly aligned address, but when numeric data is stored in a dynamically allocated buffer space, such as can be pointed to by the XSQLDA and XSQLVAR structures, the programmer must take precautions to ensure that the storage space is properly aligned.

Certain platforms, in particular those with RISC processors, require that numeric data in dynamically allocated storage structures be aligned properly in memory. Alignment is dependent both on datatype and platform.

For example, a short integer on a Sun SPARCstation must be located at an address divisible by 2, while a long on the same platform must be located at an address divisible by 4. In most cases, a data item is properly aligned if the address of its starting byte is divisible by the correct alignment number. Consult specific system and compiler documentation for alignment requirements.

A useful rule of thumb is that the size of a datatype is always a valid alignment number for the datatype. For a given type T, if size of (T) equals \( n \), then addresses divisible by \( n \) are correctly aligned for T. The following macro expression can be used to align data:

\[
\text{#define ALIGN(ptr, n) } ((\text{ptr} + n - 1) \& ~(n - 1))
\]
where \( ptr \) is a pointer to char.

The following code illustrates how the `ALIGN` macro might be used:

```c
char *buffer_pointer, *next_aligned;
next_aligned = ALIGN(buffer_pointer, sizeof(T));
```

**DSQL programming methods**

There are four possible DSQL programming methods for handling an SQL statement string. The best method for processing a string depends on the type of SQL statement in the string, and whether or not it contains placeholders for parameters. The following decision table explains how to determine the appropriate processing method for a given string.

<table>
<thead>
<tr>
<th>Is it a query?</th>
<th>Does it have placeholders?</th>
<th>Processing method to use</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>No</td>
<td>Method 1</td>
</tr>
<tr>
<td>No</td>
<td>Yes</td>
<td>Method 2</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
<td>Method 3</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Method 4</td>
</tr>
</tbody>
</table>

**Table 13.4**  SQL statement strings and recommended processing methods

**Method 1: Non-query statements without parameters**

There are two ways to process an SQL statement string containing a non-query statement without placeholder parameters:

- Use `EXECUTE IMMEDIATE` to prepare and execute the string a single time.
- Use `PREPARE` to parse the statement for execution and assign it a name, then use `EXECUTE` to carry out the statement's actions as many times as required in an application.

**Using EXECUTE IMMEDIATE**

1. To execute a statement string a single time, use `EXECUTE IMMEDIATE`:

2. Elicit a statement string from the user or create one that contains the SQL statement to be processed. For example, the following statement creates an SQL statement string:

   ```c
   char *str = "UPDATE DEPARTMENT SET BUDGET = BUDGET * 1.05";
   ```
3. Parse and execute the statement string using EXECUTE IMMEDIATE:

```sql
EXEC SQL
  EXECUTE IMMEDIATE :str;
```

**Note** EXECUTE IMMEDIATE also accepts string literals. For example,

```sql
EXEC SQL
  EXECUTE IMMEDIATE
      'UPDATE DEPARTMENT SET BUDGET = BUDGET * 1.05';
```

**Using PREPARE and EXECUTE**

To execute a statement string several times, use PREPARE and EXECUTE:

1. Elicit a statement string from the user or create one that contains the SQL statement to be processed. For example, the following statement creates an SQL statement string:

```c
char *str = "UPDATE DEPARTMENT SET BUDGET = BUDGET * 1.05";
```

2. Parse and name the statement string with PREPARE. The name is used in subsequent calls to EXECUTE:

```sql
EXEC SQL
  PREPARE SQL_STMT FROM :str;

SQL_STMT is the name assigned to the parsed statement string.
```

3. Execute the named statement string using EXECUTE. For example, the following statement executes a statement string named SQL_STMT:

```sql
EXEC SQL
  EXECUTE SQL_STMT;
```

**Note** PREPARE also accepts string literals. For example,

```sql
EXEC SQL
  PREPARE SQL_STMT FROM
      'UPDATE DEPARTMENT SET BUDGET = BUDGET * 1.05';
```

Once a statement string is prepared, it can be executed as many times as required in an application.
Method 2: Non-query statements with parameters

There are two steps to processing an SQL statement string containing a non-query statement with placeholder parameters:

1. Creating an input XSQLDA to process a statement string's parameters.
2. Preparing and executing the statement string with its parameters.

Creating the input XSQLDA

Placeholder parameters are replaced with actual data before a prepared SQL statement string is executed. Because those parameters are unknown when the statement string is created, an input XSQLDA must be created to supply parameter values at execute time. To prepare the XSQLDA, follow these steps:

1. Declare a variable to hold the XSQLDA needed to process parameters. For example, the following declaration creates an XSQLDA called in_sqlda:
   ```c
   XSQLDA *in_sqlda;
   ```
2. Optionally declare a variable for accessing the XSQLVAR structure of the XSQLDA:
   ```c
   XSQLVAR *var;
   ```
   Declaring a pointer to the XSQLVAR structure is not necessary, but can simplify referencing the structure in subsequent statements.
3. Allocate memory for the XSQLDA using the XSQLDA_LENGTH macro. The following statement allocates storage for in_sqlda:
   ```c
   in_sqlda = (XSQLDA *)malloc(XSQLDA_LENGTH(10));
   ```
   In this statement space for 10 XSQLVAR structures is allocated, allowing the XSQLDA to accommodate up to 10 parameters.
4. Set the version field of the XSQLDA to SQLDA_VERSION1, and set the sqln field to indicate the number of XSQLVAR structures allocated:
   ```c
   in_sqlda_version = SQLDA_VERSION1;
   in_sqlda->sqln = 10;
   ```

Preparing and executing a statement string with parameters

After an XSQLDA is created for holding a statement string's parameters, the statement string can be created and prepared. Local variables corresponding to the placeholder parameters in the string must be assigned to their corresponding sqldata fields in the XSQLVAR structures.

To prepare and execute a non-query statement string with parameters, follow these steps:
1. Elicit a statement string from the user or create one that contains the SQL statement to be processed. For example, the following statement creates an SQL statement string with placeholder parameters:

```
char *str = "UPDATE DEPARTMENT SET BUDGET = ?, LOCATION = ?";
```

This statement string contains two parameters: a value to be assigned to the BUDGET field and a value to be assigned to the LOCATION field.

2. Parse and name the statement string with PREPARE. The name is used in subsequent calls to DESCRIBE and EXECUTE:

```
EXEC SQL
   PREPARE SQL_STMT FROM :str;
```

SQL_STMT is the name assigned to the prepared statement string.

3. Use DESCRIBE INPUT to fill the input XSQLDA with information about the parameters contained in the SQL statement:

```
EXEC SQL
   DESCRIBE INPUT SQL_STMT USING SQL DESCRIPTOR in_sqlda;
```

4. Compare the value of the sqln field of the XSQLDA to the value of the sqld field to make sure enough XSQLVARs are allocated to hold information about each parameter. sqln should be at least as large as sqld. If not, free the storage previously allocated to the input descriptor, reallocate storage to reflect the number of parameters specified by sqld, reset sqln and version, then execute DESCRIBE INPUT again:

```
if (in_sqlda->sqld > in_sqlda->sqln)
{
   n = in_sqlda->sqld;
   free(in_sqlda);
   in_sqlda = (XSQLDA *)malloc(XSQLDA_LENGTH(n));
   in_sqlda->sqln = n;
   in_sqlda->version = SQLDA_VERSION1;
   EXEC SQL
      DESCRIBE INPUT SQL_STMT USING SQL DESCRIPTOR in_sqlda;
}
```

5. Process each XSQLVAR parameter structure in the XSQLDA. Processing a parameter structure involves up to four steps:

- Coercing a parameter’s datatype (optional).
- Allocating local storage for the data pointed to by the sqldata field of the XSQLVAR. This step is only required if space for local variables is not allocated until run time. The following example illustrates dynamic allocation of local variable storage space.
- Providing a value for the parameter consistent with its datatype (required).
- Providing a NULL value indicator for the parameter.

The following code example illustrates these steps, looping through each XSQLVAR structure in the `in_sqlda` XSQLDA:

```c
for (i=0, var = in_sqlda->sqlvar; i < in_sqlda->sqld; i++, var++)
{
    /* Process each XSQLVAR parameter structure here.
    The parameter structure is pointed to by var. */
    dtype = (var->sqltype & ~1) /* drop NULL flag for now */
    switch(dtype)
    {
        case SQL_VARYING: /* coerce to SQL_TEXT */
            var->sqltype = SQL_TEXT;
            /* Allocate local variable storage. */
            var->sqldata = (char *)malloc(sizeof(char)*var->sqllen);
            ...
            break;
        case SQL_TEXT:
            var->sqldata = (char *)malloc(sizeof(char)*var->sqllen);
            /* Provide a value for the parameter. */
            ...
            break;
        case SQL_LONG:
            var->sqldata = (char *)malloc(sizeof(long));
            /* Provide a value for the parameter. */
            *(long *)(var->sqldata) = 17;
            break;
        ...
    } /* End of switch statement. */
    if (sqltype & 1)
    {
        /* Allocate variable to hold NULL status. */
        var->sqlind = (short *)malloc(sizeof(short));
    }
} /* End of for loop. */
```

For more information about datatype coercion and NULL indicators, see “Coercing datatypes” on page 271.
6. Execute the named statement string with EXECUTE. Reference the parameters in the input XSQLDA with the USING SQL DESCRIPTOR clause. For example, the following statement executes a statement string named SQL_STMT:

```
EXEC SQL
   EXECUTE SQL_STMT USING SQL_DESCRIPTOR in_sqlda;
```

**Re-executing the statement string**

Once a non-query statement string with parameters is prepared, it can be executed as often as required in an application. Before each subsequent execution, the input XSQLDA can be supplied with new parameter and NULL indicator data.

To supply new parameter and NULL indicator data for a prepared statement, repeat steps 3–5 of “Preparing and Executing a Statement String with Parameters,” in this chapter.

---

**Method 3: Query statements without parameters**

There are three steps to processing an SQL query statement string without parameters:

1. Preparing an output XSQLDA to process the select-list items returned when the query is executed.
2. Preparing the statement string.
3. Using a cursor to execute the statement and retrieve select-list items from the output XSQLDA.

**Preparing the output XSQLDA**

Most queries return one or more rows of data, referred to as a select-list. Because the number and kind of items returned are unknown when a statement string is created, an output XSQLDA must be created to store select-list items that are returned at run time. To prepare the XSQLDA, follow these steps:

1. Declare a variable to hold the XSQLDA needed to store the column data for each row that will be fetched. For example, the following declaration creates an XSQLDA called `out_sqlda`:
   ```
   XSQLDA *out_sqlda;
   ```
2. Optionally declare a variable for accessing the XSQLVAR structure of the XSQLDA:
   ```
   XSQLVAR *var;
   ```
Declaring a pointer to the XSQLVAR structure is not necessary, but can simplify referencing the structure in subsequent statements.

3. Allocate memory for the XSQLDA using the XSQLDA_LENGTH macro. The following statement allocates storage for `out_sqlda`:

   ```c
   out_sqlda = (XSQLDA *)malloc(XSQLDA_LENGTH(10));
   ```

   Space for 10 XSQLVAR structures is allocated in this statement, enabling the XSQLDA to accommodate up to 10 select-list items.

4. Set the `version` field of the XSQLDA to SQLDA_VERSION1, and set the `sqln` field of the XSQLDA to indicate the number of XSQLVAR structures allocated:

   ```c
   out_sqlda->version = SQLDA_VERSION1;
   out_sqlda->sqln = 10;
   ```

> **Preparing a query statement string**

After an XSQLDA is created for holding the items returned by a query statement string, the statement string can be created, prepared, and described. When a statement string is executed, InterBase creates the select-list of selected rows.

To prepare a query statement string, follow these steps:

1. Elicit a statement string from the user or create one that contains the SQL statement to be processed. For example, the following statement creates an SQL statement string that performs a query:

   ```c
   char *str = "SELECT * FROM CUSTOMER";
   ```

   The statement appears to have only one select-list item (*). The asterisk is a wildcard symbol that stands for all of the columns in the table, so the actual number of items returned equals the number of columns in the table.

2. Parse and name the statement string with PREPARE. The name is used in subsequent calls to statements such as DESCRIBE and EXECUTE:

   ```c
   EXEC SQL
   PREPARE SQL_STMT FROM :str;
   ```

   `SQL_STMT` is the name assigned to the prepared statement string.

3. Use DESCRIBE OUTPUT to fill the output XSQLDA with information about the select-list items returned by the statement:

   ```c
   EXEC SQL
   DESCRIBE OUTPUT SQL_STMT INTO SQL DESCRIPTOR out_sqlda;
   ```
4. Compare the *sqln* field of the XSQLDA to the *sqld* field to determine if the output descriptor can accommodate the number of select-list items specified in the statement. If not, free the storage previously allocated to the output descriptor, reallocate storage to reflect the number of select-list items specified by *sqld*, reset *sqln* and *version*, then execute DESCRIBE OUTPUT again:

```c
if (out_sqlda->sqld > out_sqlda->sqln) {
    n = out_sqlda->sqld;
    free(out_sqlda);
    out_sqlda = (XSQLDA *)malloc(XSQLDA_LENGTH(n));
    out_sqlda->sqln = n;
    out_sqlda->version = SQLDA_VERSION1;
    EXEC SQL
        DESCRIBE OUTPUT SQL_STMT INTO SQL_DESCRIPTOR out_sqlda;
}
```

5. Set up an XSQLVAR structure for each item returned. Setting up an item structure involves the following steps:

- Coercing an item’s datatype (optional).
- Allocating local storage for the data pointed to by the *sqldata* field of the XSQLVAR. This step is only required if space for local variables is not allocated until run time. The following example illustrates dynamic allocation of local variable storage space.
- Providing a NULL value indicator for the parameter.

The following code example illustrates these steps, looping through each XSQLVAR structure in the *out_sqlda* XSQLDA:

```c
for (i=0, var = out_sqlda->sqlvar; i < out_sqlda->sqld; i++, var++) {
    dtype = (var->sqltype & ~1) /* drop flag bit for now */
    switch (dtype) {
    case SQL_VARYING:
        var->sqltype = SQL_TEXT;
        var->sqldata = (char *)malloc(sizeof(char)*var->sqllen + 2);
        break;
    case SQL_TEXT:
        var->sqldata = (char *)malloc(sizeof(char)*var->sqllen);
        break;
    case SQL_LONG:
```
var->sqldata = (char *)malloc(sizeof(long));
break;

/* process remaining types */
}
/* end of switch statements */
if (sqltype & 1)
{
  /* allocate variable to hold NULL status */
  var->sqlind = (short *)malloc(sizeof(short));
}
/* end of for loop */

For more information about datatype coercion and NULL indicators, see “Coercing datatypes” on page 271.

 Executing a statement string within the context of a cursor
To retrieve select-list items from a prepared statement string, the string must be executed within the context of a cursor. All cursor declarations in InterBase are fixed, embedded statements inserted into the application before it is compiled. DSQL application developers must anticipate the need for cursors when writing the application and declare them ahead of time.

A looping construct is used to fetch a single row at a time from the cursor and to process each select-list item (column) in that row before the next row is fetched.

To execute a statement string within the context of a cursor and retrieve rows of select-list items, follow these steps:

1. Declare a cursor for the statement string. For example, the following statement declares a cursor, DYN_CURSOR, for the SQL statement string, SQL_STMT:

   EXEC SQL
   DECLARE DYN_CURSOR CURSOR FOR SQL_STMT;

2. Open the cursor:

   EXEC SQL
   OPEN DYN_CURSOR;

Opening the cursor causes the statement string to be executed, and an active set of rows to be retrieved. For more information about cursors and active sets, see Chapter 6, “Working with Data.”
3. Fetch one row at a time and process the select-list items (columns) it contains. For example, the following loops retrieve one row at a time from DYN_CURSOR and process each item in the retrieved row with an application-specific function (here called process_column()):

```c
while (SQLCODE == 0) {
    EXEC SQL
        FETCH DYN_CURSOR USING SQL DESCRIPTOR out_sqlda;
    if (SQLCODE == 100)
        break;
    for (i = 0; i < out_sqlda->sqld; i++)
    {
        process_column(out_sqlda->sqlvar[i]);
    }
}
```

The process_column() function mentioned in this example processes each returned select-list item. The following skeleton code illustrates how such a function can be set up:

```c
void process_column(XSQLVAR *var)
{
    /* test for NULL value */
    if ((var->sqltype & 1) && (*(var->sqlind) = -1))
    {
        /* process the NULL value here */
    }
    else
    {
        /* process the data instead */
    }
    ...
}
```

4. When all the rows are fetched, close the cursor:

```c
EXEC SQL
    CLOSE DYN_CURSOR;
```

**Re-executing a query statement string**

Once a query statement string without parameters is prepared, it can be executed as often as required in an application by closing and reopening its cursor.
To reopen a cursor and process select-list items, repeat steps 2–4 of “Executing a Statement String Within the Context of a Cursor,” in this chapter.

Method 4: Query statements with parameters

There are four steps to processing an SQL query statement string with placeholder parameters:

1. Preparing an input XSQLDA to process a statement string’s parameters.
2. Preparing an output XSQLDA to process the select-list items returned when the query is executed.
3. Preparing the statement string and its parameters.
4. Using a cursor to execute the statement using input parameter values from an input XSQLDA, and to retrieve select-list items from the output XSQLDA.

Preparing the input XSQLDA

Placeholder parameters are replaced with actual data before a prepared SQL statement string is executed. Because those parameters are unknown when the statement string is created, an input XSQLDA must be created to supply parameter values at run time. To prepare the XSQLDA, follow these steps:

1. Declare a variable to hold the XSQLDA needed to process parameters. For example, the following declaration creates an XSQLDA called in_sqlda:
   ```c
   XSQLDA *in_sqlda;
   ```
2. Optionally declare a variable for accessing the XSQLVAR structure of the XSQLDA:
   ```c
   XSQLVAR *var;
   ```
   Declaring a pointer to the XSQLVAR structure is not necessary, but can simplify referencing the structure in subsequent statements.
3. Allocate memory for the XSQLDA using the XSQLDA_LENGTH macro. The following statement allocates storage for in_sqlda:
   ```c
   in_sqlda = (XSQLDA *)malloc(XSQLDA_LENGTH(10));
   ```
   In this statement, space for 10 XSQLVAR structures is allocated, allowing the XSQLDA to accommodate up to 10 input parameters. Once structures are allocated, assign values to the sqldata field in each XSQLVAR.
4. Set the `version` field of the XSQLDA to SQLDA_VERSION1, and set the `sqln` field of the XSQLDA to indicate the number of XSQLVAR structures allocated:

```c
in_sqlda->version = SQLDA_VERSION1;
in_sqlda->sqln = 10;
```

### Preparing the output XSQLDA

Because the number and kind of items returned are unknown when a statement string is executed, an output XSQLDA must be created to store select-list items that are returned at run time. To prepare the XSQLDA, follow these steps:

1. Declare a variable to hold the XSQLDA needed to process parameters. For example, the following declaration creates an XSQLDA called `out_sqlda`:

   ```c
   XSQLDA *out_sqlda;
   ```

2. Optionally declare a variable for accessing the XSQLVAR structure of the XSQLDA:

   ```c
   XSQLVAR *var;
   ```

   Declaring a pointer to the XSQLVAR structure is not necessary, but can simplify referencing the structure in subsequent statements.

3. Allocate memory for the XSQLDA using the XSQLDA_LENGTH macro. The following statement allocates storage for `out_sqlda`:

   ```c
   out_sqlda = (XSQLDA *)malloc(XSQLDA_LENGTH(10));
   ```

   Space for 10 XSQLVAR structures is allocated in this statement, enabling the XSQLDA to accommodate up to 10 select-list items.

4. Set the `version` field of the XSQLDA to SQLDA_VERSION1, and set the `sqln` field of the XSQLDA to indicate the number of XSQLVAR structures allocated:

   ```c
   out_sqlda->version = SQLDA_VERSION1;
   out_sqlda->sqln = 10;
   ```

### Preparing a query statement string with parameters

After an input and an output XSQLDA are created for holding a statement string’s parameters, and the select-list items returned when the statement is executed, the statement string can be created and prepared. When a statement string is prepared, InterBase replaces the placeholder parameters in the string with information about the actual parameters used. The information about the parameters must be assigned to the input XSQLDA (and perhaps adjusted) before the statement can be executed. When the statement string is executed, InterBase stores select-list items in the output XSQLDA.

To prepare a query statement string with parameters, follow these steps:
1. Elicit a statement string from the user or create one that contains the SQL statement to be processed. For example, the following statement creates an SQL statement string with placeholder parameters:

```
char *str = "SELECT * FROM DEPARTMENT WHERE BUDGET = ?, LOCATION = ?";
```

This statement string contains two parameters: a value to be assigned to the BUDGET field and a value to be assigned to the LOCATION field.

2. Prepare and name the statement string with PREPARE. The name is used in subsequent calls to DESCRIBE and EXECUTE:

```
EXEC SQL
    PREPARE SQL_STMT FROM :str;
```

SQL_STMT is the name assigned to the prepared statement string.

3. Use DESCRIBE INPUT to fill the input XSQLDA with information about the parameters contained in the SQL statement:

```
EXEC SQL
    DESCRIBE INPUT SQL_STMT USING SQL DESCRIPTOR in_sqlda;
```

4. Compare the sqln field of the XSQLDA to the sqld field to determine if the input descriptor can accommodate the number of parameters contained in the statement. If not, free the storage previously allocated to the input descriptor, reallocate storage to reflect the number of parameters specified by sqld, reset sqln and version, then execute DESCRIBE INPUT again:

```
if (in_sqlda->sqld > in_sqlda->sqln)
{
    n = in_sqlda->sqld;
    free(in_sqlda);
    in_sqlda = (XSQLDA *)malloc(XSQLDA_LENGTH(n));
    in_sqlda->sqln = n;
    in_sqlda->version = SQLDA_VERSION1;
    EXEC SQL
        DESCRIBE INPUT SQL_STMT USING SQL DESCRIPTOR in_sqlda;
}
```

5. Process each XSQLVAR parameter structure in the input XSQLDA. Processing a parameter structure involves up to four steps:

- Coercing a parameter’s datatype (optional).
- Allocating local storage for the data pointed to by the sqldata field of the XSQLVAR. This step is only required if space for local variables is not allocated until run time. The following example illustrates dynamic allocation of local variable storage space.
- Providing a value for the parameter consistent with its datatype (required).
- Providing a NULL value indicator for the parameter.

These steps must be followed in the order presented. The following code example illustrates these steps, looping through each XSQLVAR structure in the `in_sqlda` XSQLDA:

```c
for (i=0, var = in_sqlda->sqlvar; i < in_sqlda->sqlld; i++, var++)
{
    /* Process each XSQLVAR parameter structure here. 
    The parameter structure is pointed to by var.*/
    dtype = (var->sqltype & ~1) /* drop flag bit for now */
    switch (dtype)
    {
    case SQL_VARYING: /* coerce to SQL_TEXT */
        var->sqltype = SQL_TEXT;
        /* allocate proper storage */
        var->sqldata = (char *)malloc(sizeof(char)*var->sqllen);
        /* provide a value for the parameter. See case SQL_LONG */
        . . .
        break;
    case SQL_TEXT:
        var->sqldata = (char *)malloc(sizeof(char)*var->sqllen);
        /* provide a value for the parameter. See case SQL_LONG */
        . . .
        break;
    case SQL_LONG:
        var->sqldata = (char *)malloc(sizeof(long));
        /* provide a value for the parameter */
        *(long *)(var->sqldata) = 17;
        break;
    . . .
    } /* end of switch statement */
    if (sqltype & 1)
    {
        /* allocate variable to hold NULL status */
        var->sqlind = (short *)malloc(sizeof(short));
    }
} /* end of for loop */
```

For more information about datatype coercion and NULL indicators, see “Coercing datatypes” on page 271.
6. Use DESCRIBE OUTPUT to fill the output XSQLDA with information about the select-list items returned by the statement:

```sql
EXEC SQL
    DESCRIBE OUTPUT SQL_STMT INTO SQL_DESCRIPTOR out_sqlda;
```

7. Compare the `sqln` field of the XSQLDA to the `sqld` field to determine if the output descriptor can accommodate the number of select-list items specified in the statement. If not, free the storage previously allocated to the output descriptor, reallocate storage to reflect the number of select-list items specified by `sqld`, reset `sqln` and `version`, and execute DESCRIBE OUTPUT again:

```c
if (out_sqlda->sqld > out_sqlda->sqln)
{
    n = out_sqlda->sqld;
    free(out_sqlda);
    out_sqlda = (XSQLDA *)malloc(XSQLDA_LENGTH(n));
    out_sqlda->sqln = n;
    out_sqlda->version = SQLDA_VERSION1;
    EXEC SQL
        DESCRIBE OUTPUT SQL_STMT INTO SQL_DESCRIPTOR out_sqlda;
}
```

8. Set up an XSQLVAR structure for each item returned. Setting up an item structure involves the following steps:

- Coercing an item's datatype (optional).
- Allocating local storage for the data pointed to by the `sqldata` field of the XSQLVAR. This step is only required if space for local variables is not allocated until run time. The following example illustrates dynamic allocation of local variable storage space.
- Providing a NULL value indicator for the parameter (optional).

The following code example illustrates these steps, looping through each XSQLVAR structure in the `out_sqlda` XSQLDA:

```c
for (i=0, var = out_sqlda->sqlvar; i < out_sqlda->sqld; i++, var++)
{
    dtype = (var->sqltype & ~1) /* drop flag bit for now */
    switch (dtype)
    {
    case SQL_VARYING:
        var->sqltype = SQL_TEXT;
        break;
    case SQL_TEXT:
        var->sqldata = (char *)malloc(sizeof(char)*var->sqllen);
```
break;
case SQL_LONG:
    var->sqldata = (char *)malloc(sizeof(long));
    break;
    /* process remaining types */
} /* end of switch statements */
if (sqltype & 1)
{
    /* allocate variable to hold NULL status */
    var->sqlind = (short *)malloc(sizeof(short));
}
/* end of for loop */

For more information about datatype coercion and NULL indicators, see “Coercing datatypes” on page 271.

Executing a query statement string within the context of a cursor

To retrieve select-list items from a statement string, the string must be executed within the context of a cursor. All cursor declarations in InterBase are fixed, embedded statements inserted into the application before it is compiled. DSQL application developers must anticipate the need for cursors when writing the application and declare them ahead of time.

A looping construct is used to fetch a single row at a time from the cursor and to process each select-list item (column) in that row before the next row is fetched.

To execute a statement string within the context of a cursor and retrieve rows of select-list items, follow these steps:

1. Declare a cursor for the statement string. For example, the following statement declares a cursor, DYN_CURSOR, for the prepared SQL statement string, SQL_STMT:

   EXEC SQL
   DECLARE DYN_CURSOR CURSOR FOR SQL_STMT;

2. Open the cursor, specifying the input descriptor:

   EXEC SQL
   OPEN DYN_CURSOR USING SQL DESCRIPTOR in_sqlda;

Opening the cursor causes the statement string to be executed, and an active set of rows to be retrieved. For more information about cursors and active sets, see Chapter 6, “Working with Data.”
3. Fetch one row at a time and process the select-list items (columns) it contains. For example, the following loops retrieve one row at a time from DYN_CURSOR and process each item in the retrieved row with an application-specific function (here called process_column()):

```sql
while (SQLCODE == 0)
{
    EXEC SQL
    FETCH DYN_CURSOR USING SQL DESCRIPTOR out_sqlda;
    if (SQLCODE == 100)
        break;
    for (i = 0; i < out_sqlda->sqld; i++)
    {
        process_column(out_sqlda->sqlvar[i]);
    }
}
```

4. When all the rows are fetched, close the cursor:

```sql
EXEC SQL
CLOSE DYN_CURSOR;
```

**Re-executing a query statement string with parameters**

Once a query statement string with parameters is prepared, it can be used as often as required in an application. Before each subsequent use, the input XSQLDA can be supplied with new parameter and NULL indicator data. The cursor must be closed and reopened before processing can occur.

To provide new parameters to the input XSQLDA, follow steps 3–5 of “Preparing a Query Statement String with Parameters,” in this chapter.

To provide new information to the output XSQLDA, follow steps 6–8 of “Preparing a Query Statement String with Parameters,” in this chapter.

To reopen a cursor and process select-list items, repeat steps 2–4 of “Executing a Query Statement String Within the Context of a Cursor,” in this chapter.
This chapter describes how to preprocess a program by using `gpre`, and how to compile and link it for execution.

### Preprocessing

After coding an SQL or dynamic SQL (DSQL) program, the program must be preprocessed with `gpre` before it can be compiled. `gpre` translates SQL and DSQL commands into statements the host-language compiler accepts by generating InterBase library function calls. `gpre` translates SQL and DSQL database variables into ones the host-language compiler accepts and declares these variables in host-language format. `gpre` also declares certain variables and data structures required by SQL, such as the SQLCODE variable and the extended SQL descriptor area (XSQLDA) used by DSQL.

### Using `gpre`

The syntax for `gpre` is:

```
gpre [-language] [-options] infile [outfile]
```
The *infile* argument specifies the name of the input file.

The optional *outfile* argument specifies the name of the output file. If no file is specified, *gpre* sends its output to a file with the same name as the input file, with an extension depending on the language of the input file.

*gpre* has switches that allow you to specify the language of the source program and a number of other options. You can place the switches either before or after the input and output file specification. Each switch must include at least a hyphen preceded by a space and a unique character specifying the switch.

### Language switches

The language switch specifies the language of the source program. C and C++ are languages available on all platforms. The switches are shown in the following table:

<table>
<thead>
<tr>
<th>Switch</th>
<th>Language</th>
</tr>
</thead>
<tbody>
<tr>
<td>-c</td>
<td>C</td>
</tr>
<tr>
<td>-cxx</td>
<td>C++</td>
</tr>
</tbody>
</table>

**TABLE 14.1 gpre language switches available on all platforms**

In addition, some platforms support other languages if an additional InterBase license for the language is purchased. The following table lists the available languages and the corresponding switches:

<table>
<thead>
<tr>
<th>Switch</th>
<th>Language</th>
</tr>
</thead>
<tbody>
<tr>
<td>-al[sys]</td>
<td>Ada (Alsys)</td>
</tr>
<tr>
<td>-a[da]</td>
<td>Ada (VERDIX, VMS, Telesoft)</td>
</tr>
<tr>
<td>-ansi</td>
<td>ANSI-85 COBOL</td>
</tr>
<tr>
<td>-co[bol]</td>
<td>COBOL</td>
</tr>
<tr>
<td>-f[ortran]</td>
<td>FORTRAN</td>
</tr>
<tr>
<td>-pa[scal]</td>
<td>Pascal</td>
</tr>
</tbody>
</table>

**TABLE 14.2 Additional gpre language switches**

For example, to preprocess a C program called `census.e`, type:

```
gpre -c census.e
```
### Option switches

The option switches specify preprocessing options. The following table describes the available switches:

<table>
<thead>
<tr>
<th>Switch</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-charset name</td>
<td>Determines the active character set at compile time, where name is the character set name.</td>
</tr>
<tr>
<td>-database filename</td>
<td>Declares a database for programs. filename is the file name of the database to access. Use this option if a program contains SQL statements and does not attach to the database itself. Do not use this option if the program includes a database declaration.</td>
</tr>
<tr>
<td>-d_float</td>
<td>VAX/VMS only. Specifies that double-precision data will be passed from the application in D_FLOAT format and stored in the database in G_FLOAT format. Data comparisons within the database will be performed in G_FLOAT format. Data returned to the application from the database will be in D_FLOAT format.</td>
</tr>
<tr>
<td>-either_case</td>
<td>Enables gpre to recognize both uppercase and lowercase. Use the -either_case switch whenever SQL keywords appear in code in lowercase letters. If case is mixed, and this switch is not used, gpre cannot process the input file. This switch is not necessary with languages other than C, since they are case-insensitive.</td>
</tr>
<tr>
<td>-manual</td>
<td>Suppresses the automatic generation of transactions. Use the -m switch for SQL programs that perform their own transaction handling, and for all DSQL programs that must, by definition, explicitly control their own transactions.</td>
</tr>
<tr>
<td>-no_lines</td>
<td>Suppresses line numbers for C programs.</td>
</tr>
<tr>
<td>-output</td>
<td>Directs gpre's output to standard output, rather than to a file.</td>
</tr>
<tr>
<td>-password password</td>
<td>Specifies password, the database password, if the program connects to a database that requires one.</td>
</tr>
</tbody>
</table>

**TABLE 14.3**

| gpre option switches       |                                                            |
For sites with the appropriate license and are using a language other than C, additional gpre options can be specified, as described in the following table:

### Switch Description

- **-raw**
  Prints BLR as raw numbers, rather than as their mnemonic equivalents. This option can be useful for making the gpre output file smaller; however, it will be unreadable.

- **-sqldialect**
  Sets the SQL dialect. Valid values are 1, 2, and 3.

- **-username**
  Specifies username, the database user name, if the program connects to a database that requires one.

- **-x handle**
  Gives the database handle identified with the -database option an external declaration. This option directs the program to pick up a global declaration from another linked module. Use only if the -d switch is also used.

- **-z**
  Prints the version number of gpre and the version number of all declared databases. These databases can be declared either in the program or with the -database switch.

### Examples

The following command preprocesses a C program in a file named `appl1.e`. The output file will be `appl1.c`. Since no database is specified, the source code must connect to the database.

```bash
gpre -c appl1
```

The following command is the same as the previous, except that it does not assume the source code opens a database, instead, explicitly declaring the database, `mydb.gdb`:

```bash
gpre -c appl1 -d mydb.gdb
```
Using a file extension to specify language

In addition to using a language switch to specify the host language, it is also possible to indicate the host language with the file-name extension of the source file. The following table lists the file-name extensions for each language that gpre supports and the default extension of the output file:

<table>
<thead>
<tr>
<th>Language</th>
<th>Input file extension</th>
<th>Default output file extension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ada (VERDIX)</td>
<td>ea</td>
<td>a</td>
</tr>
<tr>
<td>Ada (Alsys, Telesoft)</td>
<td>eada</td>
<td>ada</td>
</tr>
<tr>
<td>C</td>
<td>e</td>
<td>c</td>
</tr>
<tr>
<td>C++</td>
<td>exx</td>
<td>cxx</td>
</tr>
<tr>
<td>COBOL</td>
<td>ecob</td>
<td>cob</td>
</tr>
<tr>
<td>FORTRAN</td>
<td>ef</td>
<td>f</td>
</tr>
<tr>
<td>Pascal</td>
<td>epas</td>
<td>pas</td>
</tr>
</tbody>
</table>

**TABLE 14.5** File extensions for language specification

For example, to preprocess a COBOL program called census.ecob, type:

```
gpre census_report.ecob
```

This generates an output file called census.cob.

When specifying a file-name extension, it is possible to specify a language switch as well:

```
gpre -cob census.ecob
```

Specifying the source file

Because both the language switch and the filename extension are optional, gpre can encounter three different situations:

- A language switch and input file with no extension
- No language switch, but an input file with extension
- Neither a language switch, nor a file extension

This section describes gpre's behavior in each of these cases.
**Language switch and no input file extension**

If `gpre` encounters a language switch, but the specified input file has no extension, it does the following:

1. It looks for the input file without an extension. If `gpre` finds the file, it processes it and generates an output file with the appropriate extension.

   If `gpre` does not find the input file, it looks for the file with the extension that corresponds to the indicated language. If it finds such a file, it generates an output file with the appropriate extension.

2. If `gpre` cannot find either the named file or the named file with the appropriate extension, it returns the following error:

   ```
gpre: can't open filename or filename.extension
   ```

   `filename` is the file specified in the `gpre` command. `extension` is the language-specific file extension for the specified program.

For example, suppose the following command is issued:

```bash
gpre -c census
```

`gpre` performs the following sequence of actions:

1. It looks for a file called `census` without an extension. If it finds the file, it processes it and generates `census.c`.

2. If it cannot find `census`, it looks for a file called `census.e`. If it finds `census.e`, it processes the file and generates `census.c`.

3. If it cannot find `census` or `census.e`, it returns this error:

   ```
gpre: can't open census or census.e
   ```

**No language switch and an input file with extension**

If a language switch is not specified, but the input file includes a file-name extension, `gpre` looks for the specified file and assumes the language is indicated by the extension.

For example, suppose the following command is processed:

```bash
gpre census.e
```

`gpre` looks for a file called `census.e`. If `gpre` finds this file, it processes it as a C program and generates an output file called `census.c`. If `gpre` does not find this file, it returns the following error:

```
gpre: can't open census.e
```
Neither a language switch nor a file extension

If `gpre` finds neither a language extension nor a filename extension, it looks for a file in the following order:

1. `filename.e` (C)
2. `filename.epas` (Pascal)
3. `filename.ef` (FORTRAN)
4. `filename.ecob` (COBOL)
5. `filename.ea` (VERDIX Ada)
6. `filename.eada` (Alsys, and Telesoft Ada)

If `gpre` finds such a file, it generates an output file with the appropriate extension. If `gpre` does not find the file, it returns the following error:

`gpre: can't find filename with any known extension. Giving up.`

Compiling and linking

After preprocessing a program, it must be compiled and linked. Compiling creates an object module from the preprocessed source file. Use a host-language compiler to compile the program.

The linking process resolves external references and creates an executable object. Use the tools available on a given platform to link a program's object module to other object modules and libraries, based on the platform, operating system and host language used.

Compiling an Ada program

Before compiling an Ada program, be sure the Ada library contains the package `interbase.adal` (or `interbase.a` for VERDIX Ada). This package is in the InterBase `include` directory.

To use the programs in the InterBase `examples` directory, use the package `basic_io.adal` (or `basic_io.a` for VERDIX Ada), also located in the `examples` directory.
Linking

On Unix platforms, programs can be linked to the following libraries:

- A library that uses pipes, obtained with the `-lgds` option. This library yields faster links and smaller images. It also lets your application work with new versions of InterBase automatically when they are installed.

- A library that does not use pipes, obtained with the `-lgds_b` option. This library has faster execution, but binds an application to a specific version of InterBase. When installing a new version of InterBase, programs must be relinked to use the new features or databases created with that version.

Under SunOS-4, programs can be linked to a shareable library by using the `-lgdslib` option. This creates a dynamic link at run time and yields smaller images with the execution speed of the full library. This option also provides the ability to upgrade InterBase versions automatically.

For specific information about linking options for InterBase on a particular platform, consult the online `readme` in the `interbase` directory.
This appendix covers the following topics:

- The InterBase 6 documentation set
- The printing conventions used to display information in text
- The printing conventions used to display information in syntax, code, and examples
The InterBase documentation set

The InterBase documentation set is an integrated package designed for all levels of users. It consists of six full-length printed books plus the *Installation Guide*. Each of these books is also provided in Adobe Acrobat PDF format and is accessible on line. If Adobe Acrobat is not already installed on your system, you can find it on the InterBase distribution CD-ROM or at [http://www.adobe.com/prodindex/acrobat/readstep.html](http://www.adobe.com/prodindex/acrobat/readstep.html). Acrobat is available for Windows NT, Windows 95, and most flavors of UNIX.

<table>
<thead>
<tr>
<th>Book</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Operations Guide</em></td>
<td>Provides an introduction to InterBase and an explanation of tools and procedures for performing administrative tasks on databases and database servers; also includes full reference on InterBase utilities, including <em>isql</em>, <em>gbak</em>, <em>gfix</em>, and others</td>
</tr>
<tr>
<td><em>Data Definition Guide</em></td>
<td>Explains how to create, alter, and delete database objects using the SQL language</td>
</tr>
<tr>
<td><em>Developer's Guide</em></td>
<td>Provides both reference and task-oriented material for users of the Borland RAD tools (Delphi, C++ Builder, and JBuilder); includes chapters on writing UDFs, driver configuration, developing embedded installation applications, and using the new InterBase Data Access Components</td>
</tr>
<tr>
<td><em>Language Reference</em></td>
<td>Describes the SQL language syntax and usage; includes references for procedure and trigger language, InterBase keywords, functions in the InterBase UDF library, error codes, character sets, and the system tables</td>
</tr>
<tr>
<td><em>Embedded SQL Guide</em></td>
<td>(formerly called the <em>Programmer's Guide</em>) Describes how to write embedded SQL database applications in a host language, precompiled through <em>gpre</em></td>
</tr>
<tr>
<td><em>API Guide</em></td>
<td>Explains how to write database applications using the InterBase API</td>
</tr>
</tbody>
</table>

*TABLE A.1* Books in the InterBase 6 documentation set
**Printing conventions**

The InterBase documentation set uses various typographic conventions to identify objects and syntactic elements.

The following table lists typographic conventions used in text, and provides examples of their use:

<table>
<thead>
<tr>
<th>Convention</th>
<th>Purpose</th>
<th>Example</th>
</tr>
</thead>
</table>
| **UPPERCASE** | SQL keywords, SQL functions, and names of all database objects such as tables, columns, indexes, and stored procedures | • the SELECT statement retrieves data from the CITY column in the CITIES table  
• can be used in CHAR, VARCHAR, and BLOB text columns  
• the CAST() function |
| *italic* | New terms, emphasized words, all elements from host languages, and all user-supplied items | • isc_decode_date()  
• the host variable, segment_length  
• contains six variables, or data members |
| **bold** | File names, menu picks, and all commands that are entered at a system prompt, including their switches, arguments, and parameters | • gbak, isql, gsec, gfix  
• specify the gpre-sqlida old switch  
• a script, ib_udf.sql, in the examples subdirectory  
• the employee.gdb database; the employee database  
• the Session | Advanced Settings command |

**TABLE A.2** Text conventions
### Syntax conventions

The following table lists the conventions used in syntax statements and sample code, and provides examples of their use:

<table>
<thead>
<tr>
<th>Convention</th>
<th>Purpose</th>
<th>Example</th>
</tr>
</thead>
</table>
| UPPERCASE  | Keywords that must be typed exactly as they appear when used | • SET TERM !!;  
• ADD [CONSTRAINT] CHECK |
| italic     | User-supplied parameters that cannot be broken into smaller units | • CREATE TRIGGER name FOR table;  
• ALTER EXCEPTION name 'message' |
| <italic>   | Parameters in angle brackets can be broken into smaller syntactic units; the expansion syntax for these parameters follows the current syntax statement | WHILE (<condition>) DO <compound_statement> |
| [ ]        | Optional syntax: you do not need to include anything that is enclosed in square brackets; when elements within these brackets are separated by the pipe symbol (|), you can choose only one | • CREATE [UNIQUE] [ASCENDING | DESCENDING]  
• [FILTER [FROM subtype] TO subtype] |
| { }        | You must include one and only one of the { INTO | USING} enclosed options, which are separated by the pipe symbol (|) | |
| | You can choose only one of a group whose elements are separated by this pipe symbol | SELECT [DISTINCT | ALL] |
| ...        | You can repeat the clause enclosed in brackets with the “…” symbol as many times as necessary | (<col> [,<col>…]) |

**TABLE A.3  Syntax conventions**
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