



Using the \$ZF Callout Interface

Version 2024.1
2024-05-02

Using the \$ZF Callout Interface

InterSystems IRIS Data Platform Version 2024.1 2024-05-02

Copyright © 2024 InterSystems Corporation

All rights reserved.

InterSystems®, HealthShare Care Community®, HealthShare Unified Care Record®, IntegratedML®, InterSystems Caché®, InterSystems Ensemble®, InterSystems HealthShare®, InterSystems IRIS®, and TrakCare are registered trademarks of InterSystems Corporation. HealthShare® CMS Solution Pack™ HealthShare® Health Connect Cloud™, InterSystems IRIS for Health™, InterSystems Supply Chain Orchestrator™, and InterSystems TotalView™ For Asset Management are trademarks of InterSystems Corporation. TrakCare is a registered trademark in Australia and the European Union.

All other brand or product names used herein are trademarks or registered trademarks of their respective companies or organizations.

This document contains trade secret and confidential information which is the property of InterSystems Corporation, One Memorial Drive, Cambridge, MA 02142, or its affiliates, and is furnished for the sole purpose of the operation and maintenance of the products of InterSystems Corporation. No part of this publication is to be used for any other purpose, and this publication is not to be reproduced, copied, disclosed, transmitted, stored in a retrieval system or translated into any human or computer language, in any form, by any means, in whole or in part, without the express prior written consent of InterSystems Corporation.

The copying, use and disposition of this document and the software programs described herein is prohibited except to the limited extent set forth in the standard software license agreement(s) of InterSystems Corporation covering such programs and related documentation. InterSystems Corporation makes no representations and warranties concerning such software programs other than those set forth in such standard software license agreement(s). In addition, the liability of InterSystems Corporation for any losses or damages relating to or arising out of the use of such software programs is limited in the manner set forth in such standard software license agreement(s).

THE FOREGOING IS A GENERAL SUMMARY OF THE RESTRICTIONS AND LIMITATIONS IMPOSED BY INTERSYSTEMS CORPORATION ON THE USE OF, AND LIABILITY ARISING FROM, ITS COMPUTER SOFTWARE. FOR COMPLETE INFORMATION REFERENCE SHOULD BE MADE TO THE STANDARD SOFTWARE LICENSE AGREEMENT(S) OF INTERSYSTEMS CORPORATION, COPIES OF WHICH WILL BE MADE AVAILABLE UPON REQUEST.

InterSystems Corporation disclaims responsibility for errors which may appear in this document, and it reserves the right, in its sole discretion and without notice, to make substitutions and modifications in the products and practices described in this document.

For Support questions about any InterSystems products, contact:

InterSystems Worldwide Response Center (WRC)

Tel: +1-617-621-0700

Tel: +44 (0) 844 854 2917

Email: support@InterSystems.com

Table of Contents

1 The InterSystems \$ZF Callout Interface	1
2 Overview of the \$ZF Callout Functions	3
3 Running Programs or System Commands with \$ZF(-100)	5
3.1 Introduction	5
3.2 Program Execution	6
3.3 Logging Commands and Redirecting Output	6
3.3.1 Logging Command Arguments	7
3.3.2 Using I/O Redirection	7
3.4 Adding the %System_Callout:USE Privilege	8
4 Creating an InterSystems Callout Library	9
4.1 Introduction to Callout Libraries	9
4.1.1 Creating a ZFEntry Table	11
4.2 ZFEntry Linkage Options	12
4.2.1 Introduction to Linkages	12
4.2.2 Using Numeric Linkages	13
4.2.3 Passing Null Terminated Strings with C Linkage Types	14
4.2.4 Passing Short Counted Strings with B Linkage Types	15
4.2.5 Passing Standard Counted Strings with J Linkage Types	16
4.2.6 Configuring the \$ZF Heap for Legacy Short Strings	18
4.3 Compatible Languages and Compilers	18
4.4 Callout Library Runup and Rundown Functions	19
4.5 Troubleshooting and Error Processing	19
4.5.1 Worst Practices	19
4.5.2 Handling UNIX® Signal Processing Errors	20
5 Invoking Callout Library Functions	23
5.1 Using \$ZF() to Access the iriszf Callout Library	23
5.2 Using \$ZF(-3) for Simple Library Function Calls	24
5.3 Using \$ZF(-5) to Access Libraries by System ID	25
5.4 Using \$ZF(-6) to Access Libraries by User Index	27
5.4.1 Using the \$ZF(-6) Interface to Encapsulate Library Functions	29
5.4.2 Using a Process Index for Testing	31
6 InterSystems \$ZF Callout Quick Reference	33
6.1 \$ZF(-100): Run Programs or System Commands	34
6.2 \$ZF(): Call the iriszf Library	35
6.3 \$ZF(-3): Call by Name	35
6.4 \$ZF(-5): Call by System ID	36
6.5 \$ZF(-6): Call by User Index	38

1

The InterSystems \$ZF Callout Interface

See the [Table of Contents](#) for a detailed listing of the subjects covered in this document.

The InterSystems \$ZF Callout Interface is a set of ObjectScript functions that provide several ways to integrate external system and function calls into InterSystems IRIS:

- The **\$ZF(-100)** function provides an easy way to call operating system commands and run external programs as you would from a command line interface.
- The other \$ZF functions provide various options (described below) for giving ObjectScript applications access to your frequently used C functions.

Note: The \$ZF Callout Interface is an older InterSystems technology designed primarily to give ObjectScript applications access to C function libraries. For embedded language access to external languages such as Java, .NET, Python, and Node.js, [InterSystems External Servers](#) provide an easier and more powerful alternative.

The \$ZF Callout Interface can be used for many purposes, from making simple OS command line calls to creating a function library that provides access to hundreds of functions. The following options are available:

Access to operating system calls, including calls that start external programs:

- [Running Programs or System Commands with \\$ZF\(-100\)](#)

Call system commands and run external programs as you would from a command line interface. This simple function does not require you to write a Callout library.

Callout library access. A Callout library is a user-written shared library (a DLL or SO file) that includes hooks to the \$ZF Callout Interface, allowing various **\$ZF** functions to load it at runtime and invoke its functions. Callout libraries are usually written in C, but languages with compatible calling conventions could also be used (see “[Compatible Languages and Compilers](#)”). The various \$ZF functions differ mainly in how the libraries are identified and loaded into memory:

- [Using \\$ZF\(\) to Access the iriszf Callout Library](#)

Create a special shared library named iriszf. When this library is available, its functions can be accessed without previously loading the library or specifying the library name.

- [Using \\$ZF\(-3\) for Simple Library Function Calls](#)

Load a library and invoke a function by specifying the library file path and function name. It is simple to use, but can only have one library at a time in virtual memory. Unlike the other interfaces, it does not require any initialization before a library function can be invoked.

- [Using \\$ZF\(-5\) to Access Libraries by System ID](#)

Create an interface that can be used to efficiently maintain and access more than one library at a time. Several libraries can be loaded and used simultaneously, each requiring significantly less processing overhead than **\$ZF(-3)**.

- [Using \\$ZF\(-6\) to Access Libraries by User Index](#)

Create the most efficient interface for handling a large set of Callout libraries. Libraries are accessed through a globally defined index table. The index is available to all processes in an instance of InterSystems IRIS, and several libraries can be in memory at the same time.

Also see “[Overview of \\$ZF Interfaces](#)” for a quick summary of \$ZF functions, and the “[InterSystems Callout Quick Reference](#)” for a description of all **\$ZF** functions, information on usage, and links to details and examples.

2

Overview of the \$ZF Callout Functions

The InterSystems IRIS® **\$ZF** system function is a container for a suite of related functions. Most functions in the **\$ZF** suite are identified by the first argument of the function call, which will be a negative number, `-100` or `-3` through `-6`. For example, the function that calls an operating system command has the form `$ZF(-100, <oscommand>)`, where `<oscommand>` is a string containing the command to be executed. When this function is discussed, it will be referred to as **\$ZF(-100)**. In the same way, the other functions will be referred to as **\$ZF(-3)** through **\$ZF(-6)**, using only the first parameter of the actual function call. The **\$ZF()** function can also be called without a negative number parameter, in which case it invokes functions from a special Callout library named `iriszf`.

Note: Callout Libraries

A *shared library* is a dynamically linked file (a DLL file on Windows or an SO file on UNIX® and related operating systems). A *Callout library* is a shared library that includes hooks to the \$ZF Callout Interface, allowing various **\$ZF** functions to load it at runtime and invoke library functions. See “[Creating an InterSystems Callout Library](#)” for details about how to write a Callout library.

The **\$ZF** function suite includes the following interfaces:

The \$ZF() function (with no negative number argument)

The main **\$ZF()** function provides direct access to functions from a special Callout library named `iriszf`. When you have defined and compiled this custom library, its functions can be invoked by specifying just the function name and arguments (for example, `$ZF("myFunction", arg1)`). Unlike **\$ZF(-3)**, **\$ZF(-5)**, or **\$ZF(-6)**, there is no need to load the library or specify a library identifier.

See “[Using \\$ZF\(\) to Access the iriszf Callout Library](#)” for details.

The \$ZF(-100) function

The **\$ZF(-100)** function is used to run shell commands and operating system service calls. It is not used to access Callout libraries, and can be called without any previous setup.

See “[Running Programs or System Commands with \\$ZF\(-100\)](#)” for details.

The \$ZF(-3) function

The **\$ZF(-3)** function is a simple way to load a Callout library and invoke a library function with a single statement. Both the library and its functions are specified by name, and the library remains in memory until replaced by a call to a different library.

See “[Using \\$ZF\(-3\) for Simple Library Function Calls](#)” for details.

The \$ZF(-4) function

The **\$ZF(-4)** function provides a set of services for **\$ZF(-5)** and **\$ZF(-6)**. It is a container for eight utility functions identified by the first two parameters: **\$ZF(-4,1)** through **\$ZF(-4,8)**. The **\$ZF(-5)** function interface uses functions **\$ZF(-4,1)** through **\$ZF(-4,3)**, and the **\$ZF(-6)** function interface uses functions **\$ZF(-4,5)** through **\$ZF(-4,8)**. See the following descriptions for more details.

The \$ZF(-5) function interface

The **\$ZF(-5)** function and its utility functions allow multiple libraries to be handled efficiently. Both the library and its functions are identified by system-defined ID values. Several libraries can be in virtual memory at the same time. The following **\$ZF(-4)** functions are used to load and unload libraries, and to obtain library and function ID values:

- **\$ZF(-4,1)** loads a library specified by name, and returns a library ID.
- **\$ZF(-4,2)** unloads a library.
- **\$ZF(-4,3)** returns a function ID for a specified library ID and function name.

See “[Using \\$ZF\(-5\) to Access Libraries by System ID](#)” for details.

The \$ZF(-6) function interface

The **\$ZF(-6)** function and its utility functions provide a way to write Callout applications that do not require hard-coded library names. Instead, the actual library filenames are contained in a separate index table, where each library is associated with a unique, user-defined index number. Once the index table is defined, it is available to all processes in an instance of InterSystems IRIS. Callout applications identify a library by index number and load it by reading the index table. Several libraries can be in memory at the same time. The following functions are used to manage indexes and load or unload libraries:

- **\$ZF(-6)** invokes a library function, and loads the library if it is not already in memory.
- **\$ZF(-4,4)** unloads a library.
- **\$ZF(-4,5)** and **\$ZF(-4,6)** are used to create and maintain the system index table, which can be accessed by all processes in an instance of InterSystems IRIS.
- **\$ZF(-4,7)** and **\$ZF(-4,8)** are used to create and maintain a process index table, which can be used to override the system index within a single process.

See “[Using \\$ZF\(-6\) to Access Libraries by User Index](#)” for details.

See the “[InterSystems Callout Quick Reference](#)” for a complete list of all **\$ZF** functions, information on how they are used, and links to more detailed information and examples.

3

Running Programs or System Commands with \$ZF(-100)

The **\$ZF(-100)** function permits an InterSystems IRIS® process to invoke an executable program or a command of the host operating system. This is the only \$ZF function that can be used without a special Callout shared library (see “[Creating an InterSystems Callout Library](#)”). The following topics are discussed in this chapter:

- [Introduction](#) — Overview of **\$ZF(-100)** syntax and functionality.
- [Program Execution](#) — Programs can optionally run asynchronously or within an operating system shell.
- [Logging Commands and Redirecting Output](#) — Optional settings can log commands or redirect I/O.
- [Adding the %System_Callout:USE Privilege](#) — This privilege is required to use **\$ZF(-100)**.

Also see **\$ZF(-100) (ObjectScript)** in the *ObjectScript Reference*.

Note: **\$ZF(-100)** replaces deprecated functions **\$ZF(-1)** and **\$ZF(-2)**, and should be preferred in all cases.

3.1 Introduction

\$ZF(-100) provides functionality similar to that of a command line interface, allowing you to invoke an executable program or a command of the host operating system. The syntax of this function is:

```
status = $ZF(-100, keywords, command, arguments )
```

The first argument must be a literal -100. The other three arguments specify the following information:

- *keywords* — a string containing keywords that specify various options. For example, the string "/ASYNC/LOGCMD" specifies that the program should run asynchronously and write the command line to a log file.
- *command* — a string specifying the program or system command to invoke. If the full path to an executable is not specified, the operating system will apply standard search path rules.
- *arguments* — command arguments are specified as a series of comma-delimited expressions (as demonstrated in the example below).

The **\$ZF(-100)** function returns an exit status code determined by the operating system and the program that was invoked.

The following example passes three strings to the `echo` command and then displays the status code. This example does not use any keywords, so the *keywords* argument is an empty string. The final command argument specifies a quoted string (following standard JavaScript string rules):

```
USER>set status = $ZF(-100,"","echo","hello","world","""goodbye now""")
hello world "goodbye now"

USER>write status
0
```

The following sections provide more examples for various **\$ZF(-100)** options. See “[\\$ZF\(-100\): Running Programs or System Commands](#)” in the Callout Quick Reference chapter for a summary of keywords and other options.

3.2 Program Execution

\$ZF(-100) allows you to run a program or command either synchronously or asynchronously, with or without invoking the operating system shell. The default is to execute synchronously without invoking a shell. Default execution can be overridden by specifying optional keywords in the function call.

The following keywords can be used to control program execution:

- `/ASync` — Indicates that the program should run asynchronously, allowing the **\$ZF(-100)** call to return without waiting for the program to complete.
- `/SHELL` — Indicates that the program should run in an operating system shell.

As mentioned in the last section, you can specify an empty string for the *keyword* parameter if you don’t want to use either of these options. This example deliberately tries to list nonexistent files so that an error code 1 will be generated:

```
USER>set status = $ZF(-100,"", "ls","*.scala")
ls: cannot access *.scala: No such file or directory

USER>write status
1
```

If we run the same command asynchronously, the output is not displayed and *status* is undefined because no error code has been returned:

```
USER>kill status
USER>set status = $ZF(-100,"/ASync", "ls","*.scala")
USER>write status
WRITE status
^
<UNDEFINED> *status
```

See “[Using I/O Redirection](#)” in the next section for a way to redirect error output in situations like this.

3.3 Logging Commands and Redirecting Output

The following keywords control logging and I/O redirection:

- `/LOGCMD` — causes the program command and arguments to be sent to the messages log.
- `/STDIN`, `/STDOUT`, and `/STDERR`— are used to redirect standard input, standard output, and standard error for the program invoked. These keywords must be followed by a file specification (see “[Using I/O Redirection](#)” below).

3.3.1 Logging Command Arguments

The `/LOGCMD` keyword causes command arguments and the exit status code to be logged in the messages log (<install-dir>\mgr\messages.log). This is intended primarily as a debugging tool that allows you to see how expressions passed to **\$ZF(-100)** were actually evaluated.

In most cases, the command and its arguments are logged on one line, and the return value on the next. For example, `set status=$ZF(-100,"/LOGCMD","echo","hello","world")` produces the following log entry under Windows:

```
03/28/18-11:49:51:898 (26171) 0 $ZF(-100) cmd=echo "hello" "world"
03/28/18-11:49:51:905 (26171) 0 $ZF(-100) ret=0
```

However, on UNIX® when `/SHELL` is not specified, values are logged one per line:

```
03/28/18-12:09:22:243 (26171) 0 $ZF(-100) argv[0]=echo
03/28/18-12:09:22:500 (26171) 0 $ZF(-100) argv[1]=hello
03/28/18-12:09:22:559 (26171) 0 $ZF(-100) argv[2]=world
03/28/18-12:09:22:963 (26171) 0 $ZF(-100) ret=0
```

In either case, arguments are logged exactly as they are received by the program.

3.3.2 Using I/O Redirection

The following keywords and file specifiers control I/O redirection:

- `/STDIN=`*input-file*
- `/STDOUT=`*output-file* or `/STDOUT+=`*output-file*
- `/STDERR=`*error-file* or `/STDERR+=`*error-file*

I/O redirection keywords are followed by an operator (`=` or `+=`) and a filename or file path. Spaces are permitted around the operators. Standard input should point to an existing file. The standard output and standard error files are created if they don't exist and are truncated if they already exist. Use the `=` operator to create or truncate a file, or the `+=` operator to append to an existing file. To make standard error and standard output to go to the same file, specify the same file for both keywords.

In the following example, the first line redirects the standard output from the `echo` command to file `temp.txt`., and the second line displays the resulting file contents:

```
USER>set status = $ZF(-100,"/STDOUT="temp.txt""", "echo", "-e", "three\ntwo\none\nblastoff")
USER>set status = $ZF(-100,"","cat","temp.txt")
three
two
one
blastoff
```

In this next example, we display two lines of `temp.txt` in a different way, by redirecting the file to standard input. The `tail` command accepts the input and displays the last two lines:

```
USER>set status=$ZF(-100,"/STDIN="temp.txt""", "tail", "-n2")
one
blastoff
```

This final example redirects standard error to `temp.txt`, and attempts to display a nonexistent file. It also uses the `/ASYNC` keyword to run the command asynchronously, causing the **\$ZF(-100)** call to return before the error message can be displayed.

The second line (identical to the previous example) again displays the last two lines of the file, which now contain the redirected error message:

```
USER>set status = $ZF(-100,"/ASYNC /STDERR+="temp.txt","", "cat", "nosuch.file")
USER>set status=$ZF(-100,"/STDIN="temp.txt","", "tail", "-n2")
blastoff
cat: nosuch.file: No such file or directory
```

3.4 Adding the %System_Callout:USE Privilege

\$ZF(-100) requires the **%System_Callout:USE** privilege. If your InterSystems security setting is higher than minimal, this privilege may be disabled. The following procedure describes how to enable it in the **%Developer** role:

Enabling %System_Callout:USE in the %Developer role

1. In the Management Portal go to System Administrator > Security > Roles.
2. On the *Roles* page, click on %Developer in the *Names* column.
3. On the *General* tab of the *Edit %Developer* page, find the %System_Callout privilege and click **Edit**.
4. In the *Edit resource permissions* dialog, select the **Permissions Use** checkbox if not already selected, and click **OK**.

The **%Developer** role is always created for you when you install InterSystems IRIS, but administrators may not want to make it available to all users. In some cases, it may be desirable to provide users with a role that makes **\$ZF(-100)** available but does not grant any other privileges. The following procedure creates a new role that grants only the **%System_Callout:USE** privilege:

Enabling %System_Callout:USE in a New Role

1. Open the Management Portal and go to System Administration > Security > Roles.
2. On the *Roles* page, click the **Create New Role** button to bring up the *Edit Roles* page.
3. Fill in the name and description:
 - Name: UseCallout
 - description: Grants privilege to use %System_CallOut resource

When you click **Save**, an **Add** button appears on the form.

4. Click the **Add** button to pop up a scrolling list of resources, select %System_CallOut from the list, and click **Save**. Click **Close** on the *Edit Role* form.
5. On the *Roles* page, the new **UseCallout** role is now in the list of role definitions.

4

Creating an InterSystems Callout Library

An InterSystems Callout library is a shared library that contains your custom Callout functions and the enabling code that allows InterSystems IRIS to use them. This chapter describes how to create a Callout library and access it at runtime.

The following topics are discussed:

- [Introduction to Callout Libraries](#) — describes how a Callout library is created and accessed.
- [ZFEntry Linkage Options](#) — provides a detailed description of the linkage options that determine how function arguments are passed.
- [Compatible Languages and Compilers](#) — describes how you may be able to create Callout libraries in languages other than C.
- [Callout Library Runup and Rundown Functions](#) — describes two optional functions that can be set to run automatically when a Callout library is loaded or unloaded.
- [Troubleshooting and Error Processing](#) — lists some coding practices that should be avoided, and describes special functions for handling UNIX® signal processing errors.

Note: [Shared Libraries and Callout Libraries](#)

In this book, the term *shared library* refers to a dynamically linked file (a DLL file on Windows or an SO file on UNIX® and related operating systems). A *Callout library* is a shared library that includes hooks to the \$ZF Callout Interface, allowing it to be loaded and accessed at runtime by various \$ZF functions.

4.1 Introduction to Callout Libraries

There are several different ways to access a Callout library from ObjectScript code, but the general principal is to specify the library name, the function name, and any required arguments (see “[Invoking Callout Library Functions](#)”). For example, the following code invokes a simple Callout library function:

Invoking function AddInt from Callout library simplecallout.dll

The following ObjectScript code is executed at the Terminal. It loads a Callout library named simplecallout.dll and invokes a library function named **AddInt**, which adds two integer arguments and returns the sum.

```
USER> set sum = $ZF(-3,"simplecallout.dll","AddInt",2,2)
USER> write "The sum is ",sum,!
The sum is 4
```

This example uses **\$ZF(-3)**, which is the simplest way to invoke a single Callout library function. See “[Invoking Callout Library Functions](#)” for other options.

The `simplecallout.dll` Callout library is not much more complex than the code that calls it. It contains three elements required by all Callout libraries:

1. Standard code provided when you include the `iris-cdzf.h` Callout header file.
2. One or more functions with correctly specified parameters.
3. Macro code for a *ZFEntry table*, which generates the mechanism that InterSystems IRIS will use to locate your Callout functions when the library is loaded (see “[Creating a ZFEntry Table](#)” for details).

Here is the code that was compiled to produce the `simplecallout.dll` Callout library:

Callout code for `simplecallout.dll`

```
#define ZF_DLL /* Required for all Callout code. */
#include <iris-cdzf.h> /* Required for all Callout code. */

int AddTwoIntegers(int a, int b, int *outsum) {
    *outsum = a+b; /* set value to be returned by the $ZF function call */
    return IRIS_SUCCESS; /* set the exit status code */
}
ZFBEGIN
    ZFENTRY("AddInt", "i iP", AddTwoIntegers)
ZFEND
```

- The first two lines must define `ZF_DLL` and include the `iris-cdzf.h` file. These two lines are always required.
- The **AddTwoIntegers()** function is defined next. It has the following features:
 - Two input parameters, integers *a* and *b*, and one output parameter, integer pointer **outsum*.
 - A statement assigning a value to output parameter **outsum*. This will be the value returned by the call to **\$ZF(-3)**.
 - The `return` statement does not return the function output value. Instead, it specifies the exit status code that will be received by InterSystems IRIS if the **\$ZF** call is successful. If the function fails, InterSystems IRIS will receive an exit status code generated by the system.
- The last three lines are macro calls that generate the ZFEntry table used by InterSystems IRIS to locate your Callout library functions. This example has only a single entry, where:
 - “AddInt” is the string used to identify the function in a **\$ZF** call.
 - “i iP” is a string that specifies datatypes for the two input values and the output value.
 - `AddTwoIntegers` is the entry point name of the C function.

The ZFEntry table is the mechanism that allows a shared library to be loaded and accessed by the **\$ZF** Callout Interface (see “[Creating a ZFEntry Table](#)”). A `ZFENTRY` declaration specifies the interface between the C function and the ObjectScript **\$ZF** call. Here is how the interface works in this example:

- *The C function declaration* specifies three parameters:

```
int AddTwoIntegers(int a, int b, int *outsum)
```

Parameters *a* and *b* are the inputs, and *outsum* will receive the output value. The return value of **AddTwoIntegers** is an exit status code, not the output value.

- The *ZFENTRY* macro defines how the function will be identified in InterSystems IRIS, and how the parameters will be passed:

```
ZFENTRY("AddInt","iIP",AddTwoIntegers)
```

"AddInt" is the library function identifier used to specify C function **AddTwoIntegers** in a **\$ZF** call. The linkage declaration ("iIP") declares parameters *a* and *b* as linkage type *i* (input-only integers), and *outsum* as linkage type *P* (an integer pointer that can be used for both input and output).

- The *\$ZF(-3)* function call specifies the library name, the library function identifier, and the input parameters, and returns the value of the output parameter:

```
set sum = $ZF(-3,"simplecallout.dll","AddInt",2,2)
```

Parameters *a* and *b* are specified by the last two arguments. No argument is required for the third parameter, *outsum*, because it is used only for output. The value of *outsum* is assigned to *sum* when the **\$ZF(-3)** call returns .

4.1.1 Creating a ZFEntry Table

Every Callout library must define a ZFEntry table, which allows InterSystems IRIS to load and access your Callout functions (see the “[Introduction to Callout Libraries](#)” for a simple example). The ZFEntry table is generated by a block of macro code beginning with **ZFBEGIN** and ending with **ZFEND**. Between these two macros, a **ZFENTRY** macro must be called once for each function to be exposed.

Each **ZFENTRY** call takes three arguments:

```
ZFENTRY(zfname,linkage,entrypoint)
```

where *zfname* is the string used to specify the function in a **\$ZF** call, *linkage* is a string that specifies how the arguments are to be passed, and *entrypoint* is the entry point name of the C function.

To create a Callout library, your code must contain a `#define ZF_DLL` directive, which is a switch that generates an internal **GetZFTable** function for locating library functions. When a Callout library is loaded, InterSystems IRIS calls this function to initialize the library for subsequent lookups of library function names.

Note: ZFEntry Sequence Numbers

The position of an entry in the ZFEntry table can be significant. The **\$ZF(-5)** and **\$ZF(-6)** interfaces (described in “[Invoking Callout Library Functions](#)”) both invoke a library function by specifying its sequence number (starting with 1) in the table. For example, **\$ZF(-6)** would invoke the third function in a ZFEntry table with the following call:

```
x = $ZF(-6,libID,3)
```

where *libID* is the library identifier and 3 is the sequence number of the third entry in the table.

Note: Precompiled Headers

Some compilers (such as Microsoft Visual Studio) support precompiled headers. If you use precompiled headers, the `#define ZF_DLL` statement must be in effect for the precompilation. If it is not, the resulting dll will cause a `<DYNAMIC LIBRARY LOAD>` error when it is used. It is strongly recommended that precompiled headers not be used for a Callout library.

4.2 ZFEntry Linkage Options

Each **ZFENTRY** statement (see “[Creating a ZFEntry Table](#)”) requires a string that determines how function arguments are passed. This section provides a detailed description of available linkage options.

- [Introduction to Linkages](#) — provides an overview of the various linkage types and lists all of the linkage options discussed in this chapter.
- [Using Numeric Linkages](#) — describes linkage options for numeric parameters.
- [Passing Null Terminated Strings with C Linkage Types](#) — describes linkage options for null terminated strings.
- [Passing Short Counted Strings with B Linkage Types](#) — describes linkages that use the ZARRAY structure for counted character arrays.
- [Passing Standard Counted Strings with J Linkage Types](#) — describes linkages that use the InterSystems IRIS IRIS_EXSTR structure for counted character arrays.
- [Configuring the \\$ZF Heap for Legacy Short Strings](#) — describes InterSystems IRIS system settings that control memory allocation for legacy short string parameter passing.

4.2.1 Introduction to Linkages

Each **ZFENTRY** statement (see “[Creating a ZFEntry Table](#)”) requires a string that describes how the arguments are passed. For example, “iP” specifies two parameters: an integer, and a pointer to an integer. The second letter is capitalized to specify that the second argument may be used for both input and output. Your code can have up to 32 actual and formal parameters.

If you specify an uppercase linkage type (permitted for all linkage types except i), the argument can be used for both input and output. If only one output argument is specified, its final value will be used as the return value of the function. If more than one output argument is specified, all output arguments will be returned as a comma-delimited string.

Output arguments do not have to be used as input arguments. If you specify output-only arguments after all input arguments, the function can be called without specifying any of the output arguments (see “[Introduction to Callout Libraries](#)” for an example).

From the perspective of the ObjectScript programmer, parameters are input only. The values of the actual parameters are evaluated by the **\$ZF** call and linked to the formal parameters in the C routine declaration. Any changes to the C formal parameters are either lost or are available to be copied to the **\$ZF** return value.

If the **ZFENTRY** macro does not specify a formal parameter to be used as the return value, the **\$ZF** call will return an empty string (“”). The linkage declaration can contain more than one output parameter. In this case, all the return values will be converted to a single comma-delimited string. There is no way to distinguish between the comma inserted between multiple return parameters, and a comma present in any one return value, so only the final return value should contain commas.

The following table describes the available options:

C Datatype	Input	In/Out	Notes
int	i or 4i	none (use P)	Specifies a 32-bit integer. The i linkage type is input only. To return an integer type, use P or 4P (int *). Input argument may be a numeric string (see note 1).
int *	P or 4P	P or 4P	Pointer to a 32-bit integer. Input argument may be a numeric string (see note 1).

C Datatype	Input	In/Out	Notes
_int64	8i	none (use 8P)	Specifies a 64-bit integer. To return a 64-bit integer type, use 8P. Input argument may be a numeric string (see note 1).
_int64 *	8p	8P	Pointer to a 64-bit integer. Input argument may be a numeric string (see note 1).
double *	d	D	Input argument may be a numeric string (see note 1). Use #D to preserve a double * in radix 2 format (see note 2).
float *	f	F	Input argument may be a numeric string (see note 1). Use #F to preserve a float * in radix 2 format (see note 2).
char *	1c or c	1C or C	This is the common C NULL-terminated string (see note 3).
unsigned short *	2c or w	2C or W	This is a C style NULL-terminated UTF-16 string (see note 3).
wchar_t *	4c	4C	This is a C style NULL-terminated string stored as a vector of wchar_t elements (see notes 3 and 4).
ZARRAYP	1b or b	1B or B	short 8-bit national strings (up to 32,767 characters).
ZWARRAYP	2b or s	2B or S	short 16-bit Unicode strings (up to 32,767 characters).
ZHARRAYP	4b	4B	short Unicode strings (up to 32,767 characters) stored in elements implemented by wchar_t (see note 4)
IRIS_EXSTR	1j or j	1J or J	Standard string (up to the string length limit) of 8-bit national characters
IRIS_EXSTR	2j or n	2J or N	Standard string (up to the string length limit) of 16-bit Unicode characters
IRIS_EXSTR	4j	4J	Standard string (up to the string length limit) of wchar_t characters (see note 4)

1. i, p, d, f — When numeric arguments are specified, InterSystems IRIS allows the input argument to be a string. See [“Using Numeric Linkages”](#) for details.
2. #F, #D— To preserve a number in radix 2 floating point format, use #F for float * or #D for double *. See [“Using Numeric Linkages”](#) for details.
3. 1C, 2C, 4C — All strings passed with this linkage will be truncated at the first null character. See [“Passing Null Terminated Strings with C Linkage Types”](#) for details.
4. 4B, 4C, 4J— Although wchar_t is typically 32 bits, InterSystems IRIS uses only 16 bits to store each Unicode character. An output argument containing large wchar_t values will be converted to UTF-16 for assignment to the \$ZF return value. A string containing UTF-16 (surrogate pairs) will be expanded to wchar_t for \$ZF input arguments. The true wchar_t values can be accessed using ObjectScript functions \$WASCII() and \$WCHAR().

Structure and argument prototype definitions (including InterSystems internal definitions) can be seen in the include file iris-cdzf.h.

4.2.2 Using Numeric Linkages

Numeric linkage types are provided for the following datatypes:

C Datatype	Input	In/Out	Notes
int	i	none (use P)	Specifies a 32-bit integer. The i linkage type is input only. To return an integer type, use P or 4P (int *).
int *	P	P	Pointer to a 32-bit integer.
_int64	8i	none (use 8P)	Specifies a 64-bit integer. To return a 64-bit integer type, use 8P.
_int64 *	8P	8P	Pointer to a 64-bit integer.
double *	d	D	Use #D (output only) to return a double * in radix 2 format.
float *	f	F	Use #F (output only) to return a float * in radix 2 format.

When numeric arguments are specified, InterSystems IRIS allows the input argument to be a string. When a string is passed, a leading number will be parsed from the string to derive a numeric value. If there is no leading number, the value 0 will be received. Thus "2DOGS" is received as 2.0, while "DOG" is received as 0.0. Integer arguments are truncated. For example, "2.1DOGS" is received as 2. For a detailed discussion of this subject, see "String-to-Number Conversion" in *Using ObjectScript*.

Note: Preserving Accuracy in Floating Point Numbers

When the output linkage is specified by F (float *) or D (double *), the number you return will be converted to an internal radix 10 number format. To preserve the number in radix 2 format, use #F for float * or #D for double *.

The # prefix is not permitted for input arguments. In order to avoid conversion (which may cause a slight loss in precision), input values must be created with **\$DOUBLE** in the ObjectScript code that calls the function, and the corresponding input linkages must be specified as lower case f or d.

InterSystems IRIS supports the **\$DOUBLE** function for creating a standard IEEE format 64-bit floating point number. These numbers can be passed between external functions and InterSystems IRIS without any loss of precision (unless the external function uses the 32-bit float instead of the 64-bit double). For output, the use of the IEEE format is specified by adding the prefix character # to the F or D argument type. For example, "i#D" specifies an argument list with one integer input argument and one 64-bit floating point output argument.

4.2.3 Passing Null Terminated Strings with C Linkage Types

This linkage type should be used only when you know InterSystems IRIS will not send strings containing null (`$CHAR(0)`) characters. When using this datatype, your C function will truncate a string passed by InterSystems IRIS at the first null character, even if the string is actually longer. For example, the string "ABC"_\$CHAR(0)_"DEF" would be truncated to "ABC".

C Datatype	Input	In/Out	Notes
char *	1c or c	1C or C	This is the common C NULL-terminated string.
unsigned short *	2c or w	2C or W	This is a C style NULL-terminated UTF-16 string.
wchar_t *	4c	4C	This is a C style NULL-terminated string stored as a vector of wchar_t elements.

Here is a short Callout library that uses all three linkage types to return a numeric string:

Using C linkages to pass null-terminated strings

Each of the following three functions generates a random integer, transforms it into a numeric string containing up to 6 digits, and uses a C linkage to return the string .

```
#define ZF_DLL    // Required when creating a Callout library.
#include <iris-cdzf.h>
#include <stdio.h>
#include <wchar.h>    // Required for 16-bit and 32-bit strings

int get_sample(char* retval) { // 8-bit, null-terminated
    sprintf(retval,"%d",(rand()%1000000));
    return ZF_SUCCESS;
}

int get_sample_W(unsigned short* retval) { // 16-bit, null-terminated
    swprintf(retval,6,L"%d",(rand()%1000000));
    return ZF_SUCCESS;
}

int get_sample_H(wchar_t* retval) { // 32-bit, null-terminated
    swprintf(retval,6,L"%d",(rand()%1000000));
    return ZF_SUCCESS;
}

ZFBEGIN
ZFENTRY("GetSample","1C",get_sample)
ZFENTRY("GetSampleW","2C",get_sample_W)
ZFENTRY("GetSampleH","4C",get_sample_H)
ZFEND
```

4.2.4 Passing Short Counted Strings with B Linkage Types

The iris-cdzf.h Callout header file defines counted string structures ZARRAY, ZWARRAY, and ZHARRAY, representing a short string (an InterSystems legacy string type). These structures contain an array of character elements (8-bit, 16-bit Unicode, or 32-bit wchar_t, respectively) and a short integer (maximum value 32,768) specifying the number of elements in the array. For example:

```
typedef struct zarray {
    unsigned short len;
    unsigned char data[1]; /* 1 is a dummy value */
} *ZARRAYP;
```

where

- *len* — contains the length of the array
- *data* — is an array that contains the character data. Element types are unsigned char for ZARRAY, unsigned short for ZWARRAY, and wchar_t for ZHARRAY.

The B linkages specify pointer types ZARRAYP, ZWARRAYP, and ZHARRAYP, corresponding to the three array structures. The maximum size of the array returned is 32,767 characters.

C Datatype	Input	In/Out	Notes
ZARRAYP	1b or b	1B or B	short national string containing up to 32,767 8-bit characters.
ZWARRAYP	2b or s	2B or S	short Unicode string containing up to 32,767 16-bit characters.
ZHARRAYP	4b	4B	short Unicode string containing up to 32,767 wchar_t characters.

The maximum total length of the arguments depends on the number of bytes per character (see “[Configuring the \\$ZF Heap](#)”).

Here is a Callout library that uses all three linkage types to return a numeric string:

Using B linkages to pass counted strings

Each of the following three functions generates a random integer, transforms it into a numeric string containing up to 6 digits, and uses a B linkage to return the string .

```
#define ZF_DLL    // Required when creating a Callout library.
#include <iris-cdzf.h>
#include <stdio.h>
#include <wchar.h>    // Required for 16-bit and 16-bit characters

int get_sample_Z(ZARRAYP retval) { // 8-bit, counted
    unsigned char numstr[6];
    sprintf(numstr,"%d",(rand()%1000000));
    retval->len = strlen(numstr);
    memcpy(retval->data,numstr,retval->len);
    return ZF_SUCCESS;
}

int get_sample_ZW(ZWARRAYP retval) { // 16-bit, counted
    unsigned short numstr[6];
    swprintf(numstr,6,L"%d",(rand()%1000000));
    retval->len = wcslen(numstr);
    memcpy(retval->data,numstr,(retval->len*sizeof(unsigned short)));
    return ZF_SUCCESS;
}

int get_sample_ZH(ZHARRAYP retval) { // 32-bit, counted
    wchar_t numstr[6];
    swprintf(numstr,6,L"%d",(rand()%1000000));
    retval->len = wcslen(numstr);
    memcpy(retval->data,numstr,(retval->len*sizeof(wchar_t)));
    return ZF_SUCCESS;
}

ZFBEGIN
ZFENTRY("GetSampleZ","1B",get_sample_Z)
ZFENTRY("GetSampleZW","2B",get_sample_ZW)
ZFENTRY("GetSampleZH","4B",get_sample_ZH)
ZFEND
```

Note: Commas are used as separators in an output argument string that contains multiple values. Because commas can also be a part of counted string arrays, declare these arrays at the *end* of the argument list and use one array per call.

4.2.5 Passing Standard Counted Strings with J Linkage Types

The iris-callin.h header file defines counted string structure IRIS_EXSTR, representing a standard InterSystems IRIS string. This structure contains an array of character elements (8-bit, 16-bit Unicode, or 32-bit wchar_t) and an int value (up to the string length limit) specifying the number of elements in the array:

```
typedef struct {
    unsigned int    len;        /* length of string */
    union {
        Callin_char_t *ch;      /* text of the 8-bit string */
        unsigned short *wch;    /* text of the 16-bit string */
        wchar_t *lch;          /* text of the 32-bit string */
    } str;
    /* OR unsigned short *lch if 32-bit characters are not enabled */
} IRIS_EXSTR, *IRIS_EXSTRP;
```

C Datatype	Input	In/Out	Notes
IRIS_EXSTR	1j or j	1J or J	Standard string of 8-bit national characters
IRIS_EXSTR	2j or n	2J or N	Standard string of 16-bit Unicode characters
IRIS_EXSTR	4j	4J	Standard string of 32-bit characters wchar_t characters

The IRIS_EXSTR data structure is manipulated by functions from the Callin API (a library of low-level InterSystems function calls. See the “[Callin Function Reference](#)” in *Using the Callin API* for details. Despite the similar names, the Callin API and the \$ZF Callout Interface are completely separate products).

The following functions are used to create and destroy instances of IRIS_EXSTR:

- **IrisExStrNew[W][H]** — Allocates the requested amount of storage for a string, and fills in the IRIS_EXSTR structure with the length and a pointer to the value field of the structure.
- **IrisExStrKill** — Releases the storage associated with a IRIS_EXSTR string.

Here is a Callout library that uses all three linkage types to return a numeric string:

Using J linkages to pass strings

Each of the following three functions generates a random integer, transforms it into a numeric string containing up to 6 digits, and uses a J linkage to return the string .

```
#define ZF_DLL    // Required when creating a Callout library.
#include <iris-cdzf.h>
#include <stdio.h>
#include <wchar.h>
#include <iris-callin.h>

int get_sample_L(IRIS_EXSTRP retval) { // 8-bit characters
    Callin_char_t numstr[6];
    size_t len = 0;
    sprintf(numstr,"%d",(rand()%1000000));
    len = strlen(numstr);
    IRISEXSTRKILL(retval);
    if (!IRISEXSTRNEW(retval,len)) {return ZF_FAILURE;}
    memcpy(retval->str.ch,numstr,len); // copy to retval->str.ch
    return ZF_SUCCESS;
}

int get_sample_LW(IRIS_EXSTRP retval) { // 16-bit characters
    unsigned short numstr[6];
    size_t len = 0;
    swprintf(numstr,6,L"%d",(rand()%1000000));
    len = wcslen(numstr);
    IRISEXSTRKILL(retval);
    if (!IRISEXSTRNEW(retval,len)) {return ZF_FAILURE;}
    memcpy(retval->str.wch,numstr,(len*sizeof(unsigned short))); // copy to retval->str.wch
    return ZF_SUCCESS;
}

int get_sample_LH(IRIS_EXSTRP retval) { // 32-bit characters
    wchar_t numstr[6];
    size_t len = 0;
    swprintf(numstr,6,L"%d",(rand()%1000000));
    len = wcslen(numstr);
    IRISEXSTRKILL(retval);
    if (!IRISEXSTRNEW(retval,len)) {return ZF_FAILURE;}
    memcpy(retval->str.lch,numstr,(len*sizeof(wchar_t))); // copy to retval->str.lch
    return ZF_SUCCESS;
}

ZFBEGIN
ZFENTRY("GetSampleL","1J",get_sample_L)
ZFENTRY("GetSampleLW","2J",get_sample_LW)
ZFENTRY("GetSampleLH","4J",get_sample_LH)
ZFEND
```

Note: Always kill IRIS_EXSTRP input arguments

In the previous example, IRISEXSTRKILL(retval) is always called to remove the input argument from memory. This should always be done, even if the argument is not used for output. Failure to do so may result in memory leaks.

4.2.6 Configuring the \$ZF Heap for Legacy Short Strings

Note: This section applies only to legacy short strings (see “[Passing Short Counted Strings with B Linkage Types](#)”). Standard InterSystems IRIS strings (see “[Passing Standard Counted Strings with J Linkage Types](#)”) use their own stack.

The **\$ZF** heap is the virtual memory space allocated for all **\$ZF** short string input and output parameters. It is controlled by the following InterSystems IRIS system settings:

- *ZFString* is the number of characters permitted for a single string parameter. The number of bytes this actually requires will vary depending on whether you are using 8-bit characters, 16-bit Unicode characters, or 32-bit characters on UNIX®. The permitted range for this setting is 0 to 32767 characters. The default is 0, indicating that the maximum value should be used.
- *ZFSize* is the total number of bytes InterSystems IRIS allocates for all **\$ZF** input and output parameters. The permitted range for this setting is 0 to 270336 bytes, where 0 (the default setting) indicates that InterSystems IRIS should calculate an appropriate value based on the value of *ZFString*.

Calculate *ZFSize* (total number of bytes) based on *ZFString* (maximum number of characters per string) as follows:

$$ZFSize = (<\text{bytes per character}> * ZFString) + 2050$$

For example, suppose *ZFString* has the default value of 32767 characters:

- Using Unicode 16-bit characters, an appropriate value for *ZFSize* is $(2 * 32767 + 2050) = 67584$ bytes.
- Using UNIX® 32-bit characters, an appropriate value for *ZFSize* is $(4 * 32767 + 2050) = 133118$ bytes.

These settings can be changed in either of the following places:

- The configuration parameter file (see “zfheap” in the “[config]” section of the *Configuration Parameter File Reference*)
- The Management Portal (see the *ZFSize* and *ZFString* entries under “Advanced Memory Settings” in the *Additional Configuration Settings Reference*).

4.3 Compatible Languages and Compilers

Using the \$ZF Callout Interface you can write functions in an external language and call them from ObjectScript. Callout libraries are usually written in C, but could potentially be written in any other compiled language that uses a calling convention understood by your C compiler. Two compatibility issues arise. First, the compiler must use an Application Binary Interface (ABI) that is compatible with C. Second, the compiler must generate code that does not rely on any runtime library features that are not compatible with InterSystems IRIS.

InterSystems supports using the same C compiler that we use to generate InterSystems IRIS on all platforms:

Platform	Compiler
IBM AIX	IBM XL C for AIX
Mac OS X (Darwin)	Xcode
Microsoft Windows	Microsoft Visual Studio
Linux (all variants)	GNU Project GCC C

Most platforms have a standardized Application Binary Interface (ABI), making most compilers compatible. The Intel x86-32 and x86-64 platforms are major exceptions. Multiple calling conventions exist for these platforms. See (https://en.wikipedia.org/wiki/X86_calling_conventions) for a discussion of calling conventions on these platforms.

Many C compilers allow a different calling convention to be declared for an external routine. It may be possible to call a routine written in another language by writing a C wrapper routine that declares the appropriate calling convention.

4.4 Callout Library Runup and Rundown Functions

An InterSystems Callout library can include custom internal functions that will be called when the shared object is loaded (runup) or unloaded (rundown). No arguments are passed in either case. The functions are used as follows:

- **ZFInit** — is invoked when a Callout library is first loaded by **\$ZF(-3)**, **\$ZF(-4,1)**, or **\$ZF(-6)**. The return code from this function should be zero to indicate absence of error, or non-zero to indicate some problem. If the call was successful, the address of your **ZFUnload** rundown function is saved.
- **ZFUnload** — is invoked when a Callout library is unloaded or replaced by a call to **\$ZF(-3)**, or is unloaded by **\$ZF(-4,2)** or **\$ZF(-4,4)**. It is not invoked at process halt. If some error occurs during the rundown function, further calls to it will be disabled to allow unloading of the Callout library. The return value from **ZFUnload** is currently ignored.

When building the Callout library, you may need to explicitly export the symbols **ZFInit** and **ZFUnload** during the link procedure.

4.5 Troubleshooting and Error Processing

This section discusses the following topics:

- **Worst Practices** — lists some practices that could cause serious problems.
- **Handling UNIX® Signal Processing Errors** — describes some functions to help recover from failed system calls that may happen when the process receives a signal.

4.5.1 Worst Practices

Although you can call almost any routine with the \$ZF Callout Interface, it is best used for math functions. It can also be used effectively as an interface to external devices not well handled with InterSystems IRIS I/O, or for some system services where an InterSystems IRIS interface does not otherwise exist.

The following actions can cause serious problems:

- *Accessing any memory that doesn't belong to you*
Memory access violations will be handled by InterSystems IRIS, and will be treated as bugs in InterSystems IRIS.
- *Encountering any other errors handled by traps*
Errors handled by traps (such as divide by zero errors on most platforms) will also be treated as bugs in InterSystems IRIS.
- *Changing your processes priority*
InterSystems IRIS needs to interact with other processes running InterSystems IRIS. Lowering your priority can be just as bad as raising it. For example, imagine that your process acquires a spin-lock protected resource just before

relinquishing the CPU. If your priority is too low, other processes with higher priority can fight for the resource, effectively preventing your process running so it can release the spin-lock.

- *Masking interrupts*

You might mask interrupts very briefly to implement your own interlock, but you should be very careful to not leave interrupts masked for any period of time.

- *Creating or opening any resource that you can't clean-up*

It is fine to open files, and allocate memory with `malloc`, because those resources will be closed or freed upon termination of your process. If you create a second thread, you can't guarantee the second thread will exit gracefully before the InterSystems IRIS process exits, so don't create a second thread.

- *Returning non-opaque objects from your non-ObjectScript code*

Don't `malloc` a block of memory in your code and expect to be able to use `$VIEW(address, -3, size)` to read it. Also, you should not pass a `malloc` block back to your non-ObjectScript code. Your code should return an opaque handle, and later when it receives an opaque handle it should verify that it is valid before using it.

- *Exiting your process*

You should never just call `exit`. Always return with either `ZF_SUCCESS` or `ZF_FAILURE` (and remember that the implementation of these values differs among InterSystems IRIS platforms).

- *Exiting by calling any variant of `exec`*

You can fork and then call `exec` in the child process, but be very sure that the parent will always return to InterSystems IRIS and the child process will never return to InterSystems IRIS.

- *Changing the error handling behavior for the process*

Unlike Windows, UNIX® systems only allow local error handling to be established for the current and inner frames.

4.5.2 Handling UNIX® Signal Processing Errors

When running under UNIX® and related operating systems, some system calls may fail if the process receives a signal, the most common being **open**, **read**, **write**, **close**, **ioctl**, and **pause**. If the function uses any of these system calls, your code must be able to distinguish among real errors, a `Ctrl-C`, and a call that should be restarted.

The following functions allow you to check for asynchronous events and to set a new alarm handler in **\$ZF**. The function declarations are included in `iris-cdzf.h`:

sigrtclr()

`int sigrtclr();` — Clears retry flag. Should be called once before using **sigrtchk()**.

dzfalarm()

`int dzfalarm();` — Establishes new **SIGALRM** handler.

On entry to **\$ZF**, the previous handler is automatically saved. On exit, it is restored automatically. A user program should not alter the handling of any other signal.

sigrtchk()

`int sigrtchk();` — Checks for asynchronous events. Should be called whenever one of the following system calls fails: **open**, **close**, **read**, **write**, **ioctl**, **pause**, or any call that fails when the process receives a signal. It returns a code indicating the action that the user should take:

- -1 — Not a signal. Check for I/O error. See contents of *errno* variable.

- 0 — Other signal. Restart operation from point at which it was interrupted.
- 1 — SIGINT/SIGTERM. Exit from \$ZF with a SIGTERM "return 0". These signals are trapped appropriately.

A typical **\$ZF** function used to control some device would use logic similar to the following pseudo-code:

```
if ((fd = open(DEV_NAME, DEV_MODE)) < 0) {
    Set some flags
    Call zferror
    return 0;
}
```

The **open** system call may fail if the process receives a signal. Usually this situation is not an error and the operation should be restarted. Depending on the signal, however, you might take other actions. So, in order to take account of all the possibilities, consider using the following code:

```
sigrtclr();
while (TRUE) {
    if (sigrtchk() == 1) return 1 or 0;
    if ((fd = open(DEV_NAME, DEV_MODE)) < 0) {
        switch (sigrtchk()) {
            case -1:
                /* This is probably a real device error */
                Set some flags
                Call zferror
                return 0;
            case 0:
                /* A innocuous signal was received. Restart. */
                continue;
            case 1:
                /* Someone is trying to terminate the job. */
                Do cleanup work
                return 1 or 0;
        }
    }
    else break;
}
/*
Code to handle the normal situation:
open() system call succeeded
*/
```

Note: Remember: your error processing code must never alter the handling of a signal except by calling **dzfalarm()** to establish a new SIGALRM handler.

5

Invoking Callout Library Functions

A *Callout library* is a shared library (a DLL or SO file) that includes hooks to the \$ZF Callout Interface, allowing various \$ZF functions to load it at runtime and invoke its functions. The \$ZF Callout Interface provides four different interfaces that can be used to load a Callout library at runtime and call functions from that library. These interfaces differ mainly in how the libraries are identified and loaded into memory:

- [Using \\$ZF\(\) to Access the iriszf Callout Library](#) describes how to use a special shared library named iriszf. When this library is available, its functions can be accessed by a call of the form `$ZF("funcname" , args)`, without previously loading the library or specifying the library name.
- [Using \\$ZF\(-3\) for Simple Library Function Calls](#) describes how to load a library and invoke a function by specifying the library file path and function name. It is simple to use, but can only have one library at a time in virtual memory. Unlike the other interfaces, it does not require any initialization before a library function can be invoked.
- [Using \\$ZF\(-5\) to Access Libraries by System ID](#) describes an interface that can be used to efficiently maintain and access more than one library at a time. Several libraries can be loaded and used simultaneously, each requiring significantly less processing overhead than \$ZF(-3). Libraries in memory are identified by a system-defined ID generated when the library is loaded.
- [Using \\$ZF\(-6\) to Access Libraries by User Index](#) describes the most efficient interface for handling a large set of Callout libraries. The interface provides access to libraries through a globally defined index table. The index is available to all processes in an instance of InterSystems IRIS, and several libraries can be in memory at the same time. Each indexed library is given a unique, user-defined index number, and the index table can be defined and modified at runtime. The filename associated with a given library ID can be changed when a library file is renamed or relocated, and this change will be transparent to applications that load the library by index number.

5.1 Using \$ZF() to Access the iriszf Callout Library

When a Callout library named iriszf is available in an instance's `<install_dir>/bin` directory, its functions can be invoked by a \$ZF call that specifies only the function name and arguments (for example, `$ZF("functionName" , arg1 , arg2)`). The iriszf functions can be called without previously loading the library, and are available to all processes in the instance.

A custom iriszf library is defined by creating a standard Callout library, moving it to your instance's `<install_dir>/bin` directory, and renaming it iriszf (specifically `iriszf.dll` or `iriszf.so`, depending on the platform).

Here are the steps to compile the `simplecallout.c` example (see “[Creating an InterSystems Callout Library](#)”) and set it up as an iriszf library. These examples assume an instance running under Linux, installed in a directory named `/intersystems/iris`, but the procedure is basically the same on all platforms:

1. Write and save `simplecallout.c`:

```
#define ZF_DLL
#include "iris-cdzf.h"
int AddTwoIntegers(int a, int b, int *outsum) {
    *outsum = a+b; /* set value to be returned by $ZF function call */
    return IRIS_SUCCESS; /* set the exit status code */
}

ZFBEGIN
    ZFENTRY("AddInt", "iiP", AddTwoIntegers)
ZFEND
```

2. Generate the Callout library file (`simplecallout.so`):

```
gcc -c -fPIC simplecallout.c -I /intersystems/iris/dev/iris-callin/include/ -o simplecallout.o
gcc simplecallout.o -shared -o simplecallout.so
```

3. Test the library with **\$ZF(-3)** from an InterSystems IRIS terminal session:

```
USER>write $ZF(-3,"/mytest/simplecallout.so","AddInt",1,4)
5
```

4. Now install the library for use with **\$ZF()**. Copy `simplecallout.so` into `<install_dir>/bin`, renaming it `iriszf.so`:

```
cp simplecallout.so /intersystems/iris/bin/iriszf.so
```

5. Confirm that the code can be called with **\$ZF()** from an InterSystems IRIS session:

```
USER>write $zf("AddInt",1,4)
5
```

The `iriszf` library is loaded once when first used, and never unloaded. It is completely independent of the other **\$ZF** loading and unloading operations described earlier in this chapter.

Note: **Statically Linked Libraries**

Previous versions of the **\$ZF** Callout Interface allowed code to be statically linked to the InterSystems kernel and called with **\$ZF()**. Static linking is no longer supported, but the `iriszf` library provides the same functionality without the need to relink the kernel.

5.2 Using **\$ZF(-3)** for Simple Library Function Calls

The **\$ZF(-3)** function is used to load a Callout library and execute a specified function from that library. **\$ZF(-3)** is most useful if you are only using one library, or aren't making enough calls to worry about the overhead of loading libraries. It allows you to call any available library function by specifying the library name, the function name, and a comma-separated list of function arguments:

```
result = $ZF(-3, library_name[, function_name[, arguments]])
```

The specified library is loaded if it hasn't already been loaded by a previous call to **\$ZF(-3)**. Only one library can be loaded at a time. When a subsequent **\$ZF(-3)** call specifies a different library, the old library is unloaded and the new one replaces it. The library stays loaded as long as subsequent **\$ZF(-3)** calls specify the same library. After a library has been loaded, the library name can be specified as a null string ("") in subsequent calls.

You can load or unload a library without calling a function. To load a new library, specify only the library name. To unload the current library without loading a new one, specify only a null string. In either case, **\$ZF(-3)** returns a status code indicating whether the load or unload was successful.

The following ObjectScript code calls two different functions from each of two different libraries, and then unloads the current library:

Using \$ZF(-3) to load libraries and call functions

ObjectScript

```
// define Callout library paths
set libOne = "c:\intersystems\iris\bin\myfirstlibrary.dll"
set libTwo = "c:\intersystems\iris\bin\anotherlibrary.dll"

//load and call
SET result1=$ZF(-3,libOne,"FuncA",123) // loads libOne and calls FuncA
SET result2=$ZF(-3,"","FuncB","xyz") // calls FuncB from same library

//load, then call with null name
SET status=$ZF(-3,libTwo) // unloads libOne, loads libTwo
SET result1=$ZF(-3,"","FunctionOne","arg1")
SET result2=$ZF(-3,"","FunctionTwo","argA", "argB")

//unload
SET status=$ZF(-3,"") // unloads libTwo
```

- For convenience, the library names are assigned to strings *libOne* and *libTwo*.
- The first call to **\$ZF(-3)** loads Callout library *libOne* and invokes function **FuncA** from that library.
- The second call specifies a null string for the library name, indicating that currently loaded *libOne* should be used again, and invokes function **FuncB** from that library.
- The third call to **\$ZF(-3)** specifies only library name *libTwo*. This unloads *libOne* and loads *libTwo*, but does not invoke any library functions. The call returns a status code indicating whether *libTwo* was successfully loaded.
- The fourth and fifth calls invoke library functions **FunctionOne** and **FunctionTwo** from currently loaded *libTwo*.
- The final **\$ZF(-3)** call does not invoke a library function, and specifies a null string for the library name. This unloads *libTwo* and does not load a new library. The call returns a status code indicating whether *libTwo* was successfully unloaded.

The following sections of this chapter describe **\$ZF** functions that can load more than one library at a time. These functions will not conflict with **\$ZF(-3)**. You can always use **\$ZF(-3)** as if it were loading and unloading its own private copy of a library.

5.3 Using \$ZF(-5) to Access Libraries by System ID

The **\$ZF(-5)** function uses system-defined library and function identifiers to invoke library functions. In applications that make many library function calls, this can significantly reduce processing overhead. Multiple libraries can be open at the same time. Each library only needs to be loaded once, and each library or function identifier only has to be generated once. Utility functions **\$ZF(-4,1)**, **\$ZF(-4,2)** and **\$ZF(-4,3)** are used to get the required identifiers and to load or unload libraries:

- **\$ZF(-5)** invokes a function referenced by system-defined library and function identifiers.
- **\$ZF(-4,1)** loads a library. It takes a library filename and returns a system-defined library ID value for the loaded library.
- **\$ZF(-4,2)** — unloads a Callout library specified by library ID.
- **\$ZF(-4,3)** — returns a function ID value for a given library ID and function name.

The **\$ZF(-4,1)** and **\$ZF(-4,3)** functions are used to load Callout libraries and get library and function identifiers. The syntax for **\$ZF(-4,1)** is:

```
lib_id = $ZF(-4,1,lib_name)    // get library ID
```

where *lib_name* is the full name and path of the shared library file, and *lib_id* is the returned library ID. The syntax for **\$ZF(-4,3)** is:

```
func_id=$ZF(-4,3,lib_id, func_name)    // get function ID
```

where *lib_id* is the library ID, *func_name* is the library function name, and *func_id* is the returned function ID value.

The following ObjectScript code loads Callout library mylibrary.dll and gets the library ID, then gets the function ID for "MyFunction" and invokes it with **\$ZF(-5)**:

Loading a library and invoking a function with \$ZF(-5)

ObjectScript

```
set libID = $ZF(-4,1,"C:\calloutlibs\mylibrary.dll")
set funcID = $ZF(-4,3,libID, "MyFunction")
set x = $ZF(-5,libID, funcID, "arg1")
```

Once the identifiers have been defined, the library will remain loaded until unloaded by **\$ZF(-4,2)**, and the identifiers can be used without any further calls to **\$ZF(-4,1)** or **\$ZF(-4,3)**. This eliminates a significant amount of processing overhead when functions from several libraries are invoked many times.

The following ObjectScript code loads two different libraries and invokes functions from both libraries in long loops. A function in inputlibrary.dll acquires data, and functions in outputlibrary.dll plot and store the data:

Using \$ZF(-5) with multiple libraries and many function calls

```
Method GraphSomeData(loopsizes As %Integer=100000) As %Status
{
    // load libraries and get system-defined ID values
    set InputLibID = $ZF(-4,1,"c:\intersystems\iris\bin\inputlibrary.dll")
    set OutputLibID = $ZF(-4,1,"c:\intersystems\iris\bin\outputlibrary.dll")
    set fnGetData = $ZF(-4,3,InputLibID,"GetData")
    set fnAnalyzeData = $ZF(-4,3,OutputLibID,"AnalyzeData")
    set fnPlotPoint = $ZF(-4,3,OutputLibID,"PlotPoint")
    set fnWriteData = $ZF(-4,3,OutputLibID,"WriteData")

    // call functions from each library until we have 100000 good data items
    set count = 0
    do {
        set datapoint = $ZF(-5,InputLibID,fnGetData)
        set normalized = $ZF(-5,OutputLibID,fnAnalyzeData,datapoint)
        if (normalized='') { set flatdata($INCREMENT(count)) = normalized }
    } while (count<loopsizes)
    set status = $ZF(-4,2,InputLibID)    //unload "inputlibrary.dll"

    // plot results of the previous loop and write to output
    for point=1:1:count {
        set list = $ZF(-5,OutputLibID,fnPlotPoint,flatdata(point))
        set x = $PIECE(list,"",1)
        set y = $PIECE(list,"",2)
        set sc = $ZF(-5,OutputLibID,fnWriteData,flatdata(point),x,y,"outputfile.dat")
    }
    set status = $ZF(-4,2,OutputLibID)    //unload "outputlibrary.dll"
    quit 0
}
```

- The calls to **\$ZF(-4,1)** load Callout libraries inputlibrary.dll and outputlibrary.dll into virtual memory and return system-defined library IDs for them.
- The calls to **\$ZF(-4,3)** use the library IDs and function names to get IDs for the library functions. The returned function IDs are actually ZFEntry table sequence numbers (see “[Creating a ZFEntry Table](#)” in the previous chapter).

- The first loop uses **\$ZF(-5)** to call a function from each library:
 - The **GetData()** function from inputlibrary.dll reads raw data from some unspecified source.
 - The **AnalyzeData()** function from outputlibrary.dll either normalizes the raw data or rejects it and returns an empty string.
 - Each normalized *datapoint* is stored in *flatdata(count)* (where the first call to ObjectScript function **\$INCREMENT** creates *count* and initializes it to 1).

By default, the loop fetches 100000 items. Since both libraries have been loaded and remain in memory, there is no processing overhead for switching between two different libraries.

- After the first loop ends, library inputlibrary.dll is no longer needed, so **\$ZF(-4,2)** is called to unload it. Library outputlibrary.dll will remain in memory.
- The second loop processes each item from array *flatdata* and writes it to a file at some unspecified location:
 - Library function **PlotPoint()** reads the item and returns a comma-delimited string containing the coordinates at which it will be plotted (see “[Introduction to Linkages](#)” for a description of how multiple output parameters are returned by a library function).
 - The **\$PIECE** function is used to extract coordinate values *x* and *y* from the string.
 - Library function **WriteData()** stores the item and coordinates in file outputfile.dat, which will be used by some other application to print a graph.
- After the second loop finishes, **\$ZF(-4,2)** is called again to unload library outputlibrary.dll.

The following section describes the **\$ZF(-6)** interface, which loads libraries into the same virtual memory space as the **\$ZF(-5)** interface.

5.4 Using \$ZF(-6) to Access Libraries by User Index

The **\$ZF(-6)** function provides an efficient interface that allows access to Callout libraries through a globally defined index, usable even by applications that do not know the location of the shared library files. The user-defined index table stores a key-value pair consisting of a library ID number and a corresponding library filename. The filename associated with a given library ID can be changed when a library file is renamed or relocated. This change will be transparent to applications that load the library by index number. Other **\$ZF** functions are provided to create and maintain index tables, and to unload libraries loaded by **\$ZF(-6)**.

The following **\$ZF** functions are discussed in this section:

- **\$ZF(-6)** — invokes a function from a Callout library referenced by user-specified index number. Automatically loads the library if it is not already loaded.
- **\$ZF(-4,4)** — unloads a Callout library specified by index number.
- **\$ZF(-4,5)** and **\$ZF(-4,6)** — creates or deletes an entry in the system index table. The system index is globally available to all processes within an instance of InterSystems IRIS.
- **\$ZF(-4,7)** and **\$ZF(-4,8)** — creates or deletes an entry in a process index table. Process tables are searched before the system table, so they can be used within a process to override system-wide definitions.

The **\$ZF(-6)** interface is similar to the one used by **\$ZF(-5)** (see “[Using \\$ZF\(-5\) to Access Libraries by System ID](#)”) with the following differences:

- Before **\$ZF(-6)** can be used, a library index table must be created. Library index values are user-defined, and can be changed or overridden at runtime.
- Library names are stored in the index, which does not have to be defined by the application that loads the library. The name and location of the library file can be changed in the index without affecting dependent applications that load the library by index value.
- There is no separate **\$ZF** function to load a library. Instead, a library is loaded automatically by the first **\$ZF(-6)** call that invokes one of its functions.
- It is assumed that the developer will already know the library function IDs (which are determined by their order in the ZFEntry table), so there is no **\$ZF** function that will return a function ID for a given name and library index value.

The following examples demonstrate how the **\$ZF(-6)** interface is used. The first example defines a library ID in the system index table, and the second example (which may be called from a different application) uses the library ID to invoke a library function:

Defining a system index entry with **\$ZF(-4,5)**

This example sets 100 as the library ID for mylibrary.dll in the system index table. If a definition already exists for that number, it is deleted and replaced.

ObjectScript

```
set LibID = 100
set status=$ZF(-4,4,LibID) // unload any existing library with this ID value
set status = $ZF(-4,5,LibID,"C:\calloutlibs\mylibrary.dll") // set system ID
```

- *LibID* is the index number chosen by the developer. It can be any integer greater than zero, except reserved system values 1024 through 2047.
- If a library has already been loaded with index number 100, it should be unloaded before the entry is replaced.
- The call to **\$ZF(-4,5)** associates index number 100 with library file mylibrary.dll.

Once the library ID is defined in the system index table, it is globally available to all processes within the current instance of InterSystems IRIS.

Invoking a function with **\$ZF(-6)**

This example uses the system index table created in the previous example. It uses **\$ZF(-6)** to load the library and invoke a library function, then unloads the library. This code does not have to be called from the same application that defined the library ID in the system index:

ObjectScript

```
set LibID = 100 // library ID in system index table
set FuncID = 2 // second function in library ZFEntry table
set x = $ZF(-6,LibID,FuncID,"arg1") // call function 2
set status = $ZF(-4,4,LibID) // unload the library
```

- *LibID* is the library ID defined in the system index. This application does not have to know the library name or path in order to use library functions.
- *FuncID* is the function identifier for the second function listed in the ZFEntry table of library *LibID*. It is assumed that the developer has access to the library code — the **\$ZF(-6)** interface does not have a function to retrieve this number by specifying the library function name.
- The call to **\$ZF(-6)** specifies 100 as the library ID, 2 as the function ID and "arg1" as the argument passed to the function. This call will load Callout library mylibrary.dll if it isn't already loaded, and will invoke the second function listed in the ZFEntry table.

- The call to **\$ZF(-4,4)** unloads the library. Each library loaded by **\$ZF(-6)** will remain resident until the process ends or until unloaded by **\$ZF(-4,4)**.

5.4.1 Using the \$ZF(-6) Interface to Encapsulate Library Functions

It would be simple to write an example for the **\$ZF(-6)** interface that works just like the example for the **\$ZF(-5)** interface (see “[Using \\$ZF\(-5\) to Access Libraries by System ID](#)” earlier in this chapter), but this would not demonstrate the advantages of using **\$ZF(-6)**. Instead, this section will present ObjectScript classes that allow an end user to perform exactly the same task without knowing anything about the contents or location of the Callout libraries.

The **\$ZF(-5)** example invoked functions from Callout libraries `inputlibrary.dll` and `outputlibrary.dll` to process some experimental data and produce a two-dimensional array that could be used to draw a graph. The examples in this section perform the same tasks using the following ObjectScript code:

- Class `User.SystemIndex` — encapsulates the file names and index numbers used to define entries in the system index table.
- Class `User.GraphData` — provides methods that encapsulate functions from both libraries.
- Method **GetGraph()** — is part of an end user program that calls the `User.GraphData` methods. The code in this method performs exactly the same task as the **\$ZF(-5)** example, but never calls a **\$ZF** function directly.

The `User.SystemIndex` class allows applications that use the Callout libraries to create and access system index entries without hard coding index numbers or file locations:

ObjectScript Class `User.SystemIndex`

Class Definition

```
Class User.SystemIndex Extends %Persistent
{
  /// Defines system index table entries for the User.GraphData libraries
  ClassMethod InitGraphData() As %Status
  {
    // For each library, delete any existing system index entry and add a new one
    set sc = $ZF(-4,4,..#InputLibraryID)
    set sc = $ZF(-4,5,..#InputLibraryID,"c:\intersystems\iris\bin\inputlibrary.dll")
    set sc = $ZF(-4,4,..#OutputLibraryID)
    set sc = $ZF(-4,5,..#OutputLibraryID,"c:\intersystems\iris\bin\outputlibrary.dll")
    quit 0
  }

  Parameter InputLibraryID = 100;
  Parameter OutputLibraryID = 200;
}
```

- The **InitGraphData()** method adds the libraries for `User.GraphData` to the system index table. It could be called automatically when the instance of `InterSystems IRIS` starts, making the libraries available to all processes within the instance.
- The `InputLibraryID` and `OutputLibraryID` class parameters are made available so that dependent applications don't have to hard code the index values (as demonstrated by the **Init()** method of `User.GraphData` in the following example).

The `User.GraphData` class allows end users to invoke library functions without knowing anything about the actual Callout libraries.

ObjectScript Class User.GraphData

Class Definition

```

Class User.GraphData Extends %Persistent
{
  /// Gets library IDs and updates the system index table for both libraries.
  Method Init() As %Status
  {
    set InLibID = ##class(User.GraphDataIndex).%GetParameter("InputLibraryID")
    set OutLibID = ##class(User.GraphDataIndex).%GetParameter("OutputLibraryID")
    quit ##class(User.SystemIndex).InitGraphData()
  }
  Property InLibID As %Integer [Private];
  Property OutLibID As %Integer [Private];

  /// Calls function "FormatData" in library "inputlibrary.dll"
  Method FormatData(rawdata As %Double) As %String
  {
    quit $ZF(-6,..InLibID,1,rawdata)
  }
  /// Calls function "RefineData" in library "outputlibrary.dll"
  Method RefineData(midvalue As %String) As %String
  {
    quit $ZF(-6,..OutLibID,1,midvalue)
  }
  /// Calls function "PlotGraph" in library "outputlibrary.dll"
  Method PlotGraph(datapoint As %String, xvalue As %Integer) As %String
  {
    quit $ZF(-6,..OutLibID,2,datapoint,xvalue)
  }
  /// Unloads both libraries
  Method Unload() As %String
  {
    set sc = $ZF(-4,4,..InLibID)    // unload "inputlibrary.dll"
    set sc = $ZF(-4,4,..OutLibID)   // unload "outputlibrary.dll"
    quit 0
  }
}

```

- The **Init()** method calls a class method from User.SystemIndex that will set or update the system index entries for inputlibrary.dll and outputlibrary.dll. It also gets the current values for the library IDs. The developer of this class still needs to know something about the Callout library code, but future changes to the system index will be transparent.
- Methods **FormatData()**, **RefineData()**, and **PlotGraph()** each encapsulate a call to one library function. Since they contain only the unconditional **\$ZF** function calls, they will be optimized to run just as fast as the original **\$ZF** calls.
- The **Unload()** method unloads either or both libraries.

The following example demonstrates how an end user might use the methods in User.GraphData. The **GetGraph()** method uses the Callout libraries to perform exactly the same task as the **GraphSomeData()** method in the **\$ZF(-5)** interface example (see “[Using \\$ZF\(-5\) to Access Libraries by System ID](#)” earlier in this chapter), but it does not directly call any **\$ZF** functions:

Method GetGraph()

```

Method GetGraph(loopsizes As %Integer = 100000) As %Status
{
  // Get an instance of class GraphData and initialize the system index
  set graphlib = ##class(User.GraphData).%New()
  set sc = graphlib.Init()

  // call functions from both libraries repeatedly
  // each library is loaded automatically on first call
  for count=1:1:loopsizes {
    set midvalue = graphlib.FormatData(^rawdata(count))
    set flatdata(count) = graphlib.RefineData(midvalue)
  }

  // plot results of the previous loop
  for count=1:1:loopsizes {

```

```

        set x = graphlib.PlotGraph(flatdata(count),0)
        set y = graphlib.PlotGraph(flatdata(count),x)
        set ^graph(x,y) = flatdata(count)
    }

    //return after unloading all libraries loaded by $ZF(-6)
    set status = graphlib.Unload()
    quit 0
}

```

- The User.GraphData class is instantiated as *graphlib*, and the **Init()** method is called to initialize the system index. This method does not necessarily have to be called here, since the system index only has to be initialized once for all processes in an instance of InterSystems IRIS.
- The first loop indirectly uses **\$ZF(-6)** to call a functions from each library, and **\$ZF(-6)** automatically loads each library the first time it is needed. Library inputlibrary.dll is loaded by the first call to **FormatData()**, and outputlibrary.dll is loaded on the first call to **RefinedData()**.
- The second loop invokes **PlotGraph()** from library outputlibrary.dll, which has already been loaded.
- The call to **Unload()** indirectly calls **\$ZF(-4,4)** on both libraries.

5.4.2 Using a Process Index for Testing

As previously mentioned, a process index table is searched before the system index table, so it can be used within a process to override system-wide definitions. The following example creates a process index that is used to test a new version of one of the libraries used in the previous section.

Using a process index to test a new version of "inputlibrary.dll"

ObjectScript

```

// Initialize the system index and generate output from standard library
set testlib = ##class(User.GraphData).%New()
set sc = testlib.Init()
set sc = graphgen.GetGraph() // get 100000 data items by default
merge testgraph1 = ^graph
kill ^graph

// create process index and test new library with same instance of testproc
set sc = $ZF(-4,4,100) // unload current copy of inputlib
set sc = $ZF(-4,8) // delete existing process index, if any
set sc = $ZF(-4,7,100, "c:\testfiles\newinputlibrary.dll") // override system index
set sc = graphgen.GetGraph()
merge testgraph2 = ^graph

// Now compare testdata1 and testdata2

```

- In the first three lines, this test code initializes the system index and generates a graph, just like the previous example. The graph has been plotted using the standard version of inputlibrary.dll (identified by the system index entry with ID value 100), and has been saved to *testgraph1*.
- The call to **\$ZF(-4,4)** unloads inputlibrary.dll, which is identified by library ID 100 in the system index table.
- **\$ZF(-4,8)** is called without specifying a library ID, indicating that all entries in the current process index table are to be deleted.
- The call to **\$ZF(-4,7)** adds an entry to the process index table that sets 100 as the library ID for test library newinputlibrary.dll. This overrides the entry for that ID in the system index. Library ID 100 now points to newinputlibrary.dll rather than inputlibrary.dll.
- **GetGraph()** is called again, using the same instance of User.GraphData. Nothing has changed except that the standard version of inputlibrary.dll has been unloaded, so **GetGraph()** will now load and use the new version of the library. The test then compares graphs *testgraph1* and *testgraph2* to verify that both versions are producing the same results.

6

InterSystems \$ZF Callout Quick Reference

The **\$ZF()** function provides a set of subordinate functions identified by one or two numeric arguments (for example, the **\$ZF(-100)** subordinate function runs an external program or system command, and the **\$ZF(-4,1)** subordinate function loads a Callout library). The following list shows only the arguments that identify a specific **\$ZF()** subordinate function. Most of these functions also take additional arguments, as described in the detailed entry for each function.

Detailed function descriptions are organized under the following headings:

- **\$ZF(-100): Run Programs or System Commands**
 - **\$ZF(-100)** — executes a program or system command. Also see **\$ZF(-100) (ObjectScript)** in the *ObjectScript Reference*.
- **\$ZF(): Call the iriszf Library**
 - **\$ZF()** (no subordinate function arguments) — attempts to invoke a function from a custom Callout library named `iriszf` located in the `bin` directory of the current instance. Also see **\$ZF() (ObjectScript)** in the *ObjectScript Reference*.
- **\$ZF(-3): Call by Name**
 - **\$ZF(-3)** — loads a Callout library and invokes a library function. Also see **\$ZF(-3) (ObjectScript)** in the *ObjectScript Reference*.
- **\$ZF(-5): Call by System ID**
 - **\$ZF(-5)** — invokes a function from a Callout library referenced by system-defined ID number.
 - **\$ZF(-4,1)** — loads a Callout library specified by name, and returns an ID number for it.
 - **\$ZF(-4,2)** — unloads a Callout library specified by ID number, or unloads all libraries.
 - **\$ZF(-4,3)** — returns an ID number for a function in the specified library.

Also see **\$ZF(-5) (ObjectScript)** and **\$ZF(-4) (ObjectScript)** in the *ObjectScript Reference*.
- **\$ZF(-6): Call by User Index**
 - **\$ZF(-6)** — invokes a function from a Callout library referenced by user-specified index number.
 - **\$ZF(-4,4)** — unloads a Callout library specified by index number.
 - **\$ZF(-4,5)** — creates an entry in the Callout system index table
 - **\$ZF(-4,6)** — deletes an entry in the Callout system index table
 - **\$ZF(-4,7)** — creates an entry in the Callout process index table

- **\$ZF(-4,8)** — deletes an entry in the Callout process index table

Also see **\$ZF(-6) (ObjectScript)** and **\$ZF(-4) (ObjectScript)** in the *ObjectScript Reference*.

6.1 \$ZF(-100): Run Programs or System Commands

The **\$ZF(-100)** function is used to run an external program or system command, or to launch an operating system shell. This is the only **\$ZF** function that can be used without a Callout library (see “[Running Programs or System Commands with \\$ZF\(-100\)](#)” for more information and examples).

\$ZF(-100)

Executes a program or an operating system command.

```
$ZF(-100, keyword_flags, program, arguments )
```

parameters:

- *keyword_flags* — (optional) A string expression consisting of a sequence of flags of the form `/keyword`. Keywords can be in upper or lowercase, and blanks are allowed between flags. I/O redirection keywords are followed by an operator and a path string (`/keyword=path` or `/keyword+=path`) as described below (see “[Specifying Keywords](#)”).
- *program* — Specifies the program to be executed. It can be a full path or simply a name, in which case the usual operating system search path rules are followed.
- *arguments* — (optional) A comma-delimited list of program arguments. A variable number of parameters can be also be specified with *arg...* syntax (see “[Variable Number of Parameters](#)” in *Using ObjectScript*).

returns:

One of the following status codes:

- `-1` — An operating system error occurred and the details are logged in SYSLOG.
- `0` — If `/ASYNCH` is specified, indicates that the program was successfully started.
- *status* — If `/ASYNCH` is not specified, *status* is the exit code (0 or a positive number) returned by the program when it ends.

Specifying Keywords

The following keywords control program execution and logging:

- `/SHELL` — Indicates that the program should be invoked within an operating system shell. The default is to not use a shell.
- `/ASYNCH` — Indicates that the program should run asynchronously, allowing the **\$ZF(-100)** call to return without waiting for it to complete.
- `/LOGCMD` — Causes the program command line to be logged in `messages.log`. This is a debugging tool that provides a way to view the arguments exactly as they are received by the program.

The following keywords and file specifiers control I/O redirection:

- `/STDIN=input-file`

- `/STDOUT=output-file` or `/STDOUT+=output-file`
- `/STDERR=error-file` or `/STDERR+=error-file`

I/O redirection keywords are followed by an operator (`=` or `+=`) and a filename or file path. Spaces are permitted around the operators. Standard input should point to an existing file. The standard output and standard error files are created if they don't exist and are truncated if they already exist. Use the `=` operator to create or truncate a file, or the `+=` operator to append to an existing file. To make standard error and standard output to go to the same file, specify the same file for both keywords.

see also:

See “[Running Programs or System Commands with \\$ZF\(-100\)](#)” for more information and examples. Also see [\\$ZF\(-100\) \(ObjectScript\)](#) in the *ObjectScript Reference*.

6.2 \$ZF(): Call the iriszf Library

If **\$ZF()** is called without a negative number argument (for example, `$ZF("myFunction", arg)`), it attempts to invoke a function from a custom Callout library named `iriszf` (see “[Using \\$ZF\(\) to Access the iriszf Callout Library](#)”).

\$ZF()

Tries to invoke a function from a custom Callout library named `iriszf`. Once you have created and installed this library, its functions are immediately available to **\$ZF()** without the need to load the library or specify a library identifier.

```
retval = $ZF(func_name[, arg1[, ...argN]])
```

parameters:

- *func_name* — The name of the library function as specified in the ZFEntry table (see “[Creating a ZFEntry Table](#)”).
- *args* — (optional) a comma-delimited list containing any arguments required by the library function.

returns:

- *retval* — the output value of the library function, or NULL if the library function does not set an output value.

see also:

See “[Creating an InterSystems Callout Library](#)” and “[Using \\$ZF\(\) to Access the iriszf Callout Library](#)” for details and examples. Also see **\$ZF() (ObjectScript)** in the *ObjectScript Reference*.

6.3 \$ZF(-3): Call by Name

The **\$ZF(-3)** and **\$ZF(-5)** functions allow an application to load InterSystems Callout shared libraries and invoke library functions at runtime. Library paths and library function names must be known by the calling application. **\$ZF(-3)** specifies library and function names as arguments. **\$ZF(-5)** specifies libraries and functions by system-defined ID numbers. Before **\$ZF(-5)** can be used, the ID numbers must be obtained by calling utility functions (**\$ZF(-4,1)** through **\$ZF(-4,3)**) that take library and function names as arguments.

\$ZF(-3)

Loads a Callout library and executes a library function. Only one **\$ZF(-3)** library may be loaded at a time. If a call to **\$ZF(-3)** specifies a different library from the previous call, the previous library is unloaded and replaced.

```
retval = $ZF(-3, lib_name, func_name[, arg1[, ...argN]])  
retval = $ZF(-3, lib_name, func_id[, arg1[, ...argN]])
```

parameters:

- *lib_name* — The name of the Callout library as specified in the ZFEntry table (see “[Creating a ZFEntry Table](#)”). If a library has already been loaded by a previous call to **\$ZF(-3)**, an empty string (" ") can be used to specify the current library.
- *func_name* — The name of the function to look up within the Callout library.
- *func_id* — sequence number of the library function within the ZFEntry table. If this number is known, it may be used instead of the function name for faster access (entries are numbered consecutively from 1).
- *args* — (optional) a comma-delimited list containing any arguments required by the library function.

returns:

- *retval* — the output value of the library function, or NULL if the library function does not set an output value.

see also:

See “[Using \\$ZF\(-3\) for Simple Library Function Calls](#)” for details and examples. See **\$ZF(-4,3)** for another way to obtain the ZFEntry table sequence number. Also see **\$ZF(-3) (ObjectScript)** in the *ObjectScript Reference*.

6.4 \$ZF(-5): Call by System ID

The **\$ZF(-5)** function allows an application to load InterSystems Callout shared libraries and invoke library functions at runtime. Library paths and library function names must be known by the calling application. Libraries and functions are specified by system-defined ID numbers.

Utility functions **\$ZF(-4,1)**, **\$ZF(-4,2)**, and **\$ZF(-4,3)** are used only with **\$ZF(-5)**. They provide services to acquire library ID numbers and to load or unload libraries.

\$ZF(-5)

Calls a function from a Callout library referenced by system-defined ID number.

```
retval = $ZF(-5, lib_id, func_id, args)
```

parameters:

- *lib_id* — The Callout library ID number supplied by **\$ZF(-4,1)**.
- *func_id* — The library function ID number supplied by **\$ZF(-4,3)**.
- *args* — (optional) a comma-delimited list containing any arguments required by the library function.

returns:

- *retval* — The output value of the library function, or NULL if the library function does not set an output value.

see also:

See “[Using \\$ZF\(-5\) to Access Libraries by System ID](#)” for details and examples. Also see [\\$ZF\(-5\) \(ObjectScript\)](#) and [\\$ZF\(-4\) \(ObjectScript\)](#) in the *ObjectScript Reference*.

\$ZF(-4, 1)

Utility function used with [\\$ZF\(-5\)](#). Loads a Callout library specified by name, and returns an ID number for it.

```
lib_id = $ZF(-4,1, lib_name)
```

parameter:

- *lib_name* — The name of the Callout library to be loaded.

returns:

- *lib_id* — A system-defined identifier used to reference *lib_name*.

see also:

See “[Using \\$ZF\(-5\) to Access Libraries by System ID](#)” for details and examples. Also see [\\$ZF\(-5\) \(ObjectScript\)](#) and [\\$ZF\(-4\) \(ObjectScript\)](#) in the *ObjectScript Reference*.

\$ZF(-4, 2)

Utility function used with [\\$ZF\(-5\)](#). Unloads a Callout library specified by ID number. If no ID is specified, it unloads all libraries in the process that were loaded by either [\\$ZF\(-4,1\)](#) or [\\$ZF\(6\)](#). Does not unload the library loaded by [\\$ZF\(-3\)](#).

```
$ZF(-4,2[,lib_id])
```

parameter:

- *lib_id* — The system-defined identifier returned by [\\$ZF\(-4,1\)](#). If not specified, all libraries loaded by [\\$ZF\(-4,1\)](#) or [\\$ZF\(6\)](#) are unloaded.

see also:

See “[Using \\$ZF\(-5\) to Access Libraries by System ID](#)” for details and examples. Also see “[Using a Process Index for Testing](#)” for an example using [\\$ZF\(-4,2\)](#) without a library ID parameter. Also see [\\$ZF\(-5\) \(ObjectScript\)](#) and [\\$ZF\(-4\) \(ObjectScript\)](#) in the *ObjectScript Reference*.

\$ZF(-4, 3)

Utility function used with [\\$ZF\(-5\)](#). Returns an ID number for a function with the specified library ID and function name. This number is actually the sequence number of the function within the ZFEntry table (see “[Creating a ZFEntry Table](#)”).

```
func_id = $ZF(-4,3, lib_id, func_name)
```

parameters:

- *lib_id* — The system-defined library identifier returned by [\\$ZF\(-4,1\)](#).
- *func_name* — The name of the function to look up within the Callout library.

returns:

- *func_id* — The returned ID number for the specified library function.

see also:

See “[Using \\$ZF\(-5\) to Access Libraries by System ID](#)” for details and examples. Also see [\\$ZF\(-5\) \(ObjectScript\)](#) and [\\$ZF\(-4\) \(ObjectScript\)](#) in the *ObjectScript Reference*.

Note: For utility functions [\\$ZF\(-4, 4\)](#) through [\\$ZF\(-4, 8\)](#), see the next section (“[\\$ZF\(-6\): Call by User Index](#)”)

6.5 \$ZF(-6): Call by User Index

The [\\$ZF\(-6\)](#) interface provides access to Callout libraries through a user-defined index table, usable even by applications that do not know the location of the shared library files.

Utility functions [\\$ZF\(-4, 4\)](#) through [\\$ZF\(-4, 8\)](#) are used only by [\\$ZF\(-6\)](#). They provide services to unload libraries and to create or maintain indexes.

[\\$ZF\(-6\)](#)

Look up and execute a function in an indexed Callout library.

```
retval = $ZF(-6, lib_index, func_id, args)
```

parameters:

- *lib_index* — A user-specified index to a Callout library (created by [\\$ZF\(-4,5\)](#) or [\\$ZF\(-4,7\)](#))
- *func_id* — (optional) The ID number of the function within the Callout library, which is the function index in the library's ZFEntry table. If omitted, call verifies the validity of *lib_index*, loads the library, and returns the full library filename.
- *args* — (optional) a comma-delimited list containing any arguments required by the library function.

returns:

- *retval* — The output value of the library function, or NULL if the library function does not set an output value.

see also:

See “[Using \\$ZF\(-6\) to Access Libraries by User Index](#)” for details and examples. Also see [\\$ZF\(-6\) \(ObjectScript\)](#) and [\\$ZF\(-4\) \(ObjectScript\)](#) in the *ObjectScript Reference*.

Note: For utility functions [\\$ZF\(-4, 1\)](#), [\\$ZF\(-4, 2\)](#), and [\\$ZF\(-4, 3\)](#), see the previous section (“[\\$ZF\(-5\): Call by System ID](#)”)

[\\$ZF\(-4, 4\)](#)

Utility function used with [\\$ZF\(-6\)](#). Unloads a Callout library specified by index number.

```
$ZF(-4, 4, lib_index)
```

parameter:

- *lib_index* — A user-specified Callout library index number (created by [\\$ZF\(-4,5\)](#) or [\\$ZF\(-4,7\)](#))

see also:

See “[Using \\$ZF\(-6\) to Access Libraries by User Index](#)” for details and examples. Also see [\\$ZF\(-6\) \(ObjectScript\)](#) and [\\$ZF\(-4\) \(ObjectScript\)](#) in the *ObjectScript Reference*.

\$ZF(-4, 5)

Utility function used with **\$ZF(-6)**. Creates an entry in the Callout system index table.

```
$ZF(-4, 5, lib_index, lib_name)
```

parameters:

- *lib_index* — A unique user-specified number that will be used to reference the Callout library.
- *lib_name* — The name of the Callout library to be indexed.

see also:

Details and examples in “[Using \\$ZF\(-6\) to Access Libraries by User Index](#)”. Also see **\$ZF(-6) (ObjectScript)** and **\$ZF(-4) (ObjectScript)** in the *ObjectScript Reference*.

\$ZF(-4, 6)

Utility function used with **\$ZF(-6)**. Deletes an entry in the Callout system index table.

```
$ZF(-4, 6, lib_index)
```

parameters:

- *lib_index* — An index number previously defined by a call to **\$ZF(-4,5)**. This argument is required (unlike **\$ZF(-4,8)**, where it can be omitted).

see also:

See “[Using \\$ZF\(-6\) to Access Libraries by User Index](#)” for details and examples. Also see **\$ZF(-6) (ObjectScript)** and **\$ZF(-4) (ObjectScript)** in the *ObjectScript Reference*.

\$ZF(-4,7)

Utility function used with **\$ZF(-6)**. Creates an entry in the Callout process index table.

```
$ZF(-4, 7, lib_index, lib_name)
```

parameters:

- *lib_index* — A unique user-specified number that will be used to reference the Callout library.
- *lib_name* — The name of the Callout library to be indexed.

see also:

See “[Using \\$ZF\(-6\) to Access Libraries by User Index](#)” for details and examples. Also see **\$ZF(-6) (ObjectScript)** and **\$ZF(-4) (ObjectScript)** in the *ObjectScript Reference*.

\$ZF(-4,8)

Utility function used with **\$ZF(-6)**. Deletes an entry from the Callout process index table. If no index number is specified, all index entries are deleted.

```
$ZF(-4, 8, lib_index)
```

parameters:

- *lib_index* — (optional) An index number previously defined by a call to **\$ZF(-4,7)**. If not specified, all index entries are deleted.

see also:

See “[Using \\$ZF\(-6\) to Access Libraries by User Index](#)” for details and examples. Also see [\\$ZF\(-6\) \(ObjectScript\)](#) and [\\$ZF\(-4\) \(ObjectScript\)](#) in the *ObjectScript Reference*.