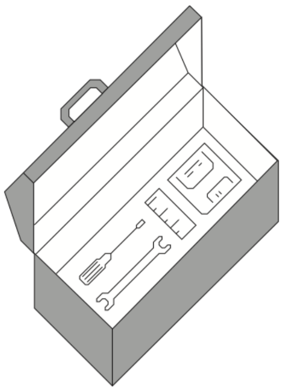

IGOR XOP TOOLKIT

REFERENCE MANUAL

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Introduction to XOPs

About This Manual

This manual describes XOP Toolkit 8. It focuses on development using Xcode 11 or later on Macintosh and Visual C++ 2015, 2017 or 2019 on Windows. XOP Toolkit 8 creates XOPs that require Igor Pro 8.00 or later.

If your XOP must run with Igor Pro 6 or 7, or if you are updating an old XOP, you should use XOP Toolkit 7. See **Choosing Which XOP Toolkit to Use** on page 5 for details.

If you are new to XOP programming, we recommend that you start by reading the first four chapters of this manual.

This chapter provides an overview, orientation and background information.

Chapter 2 is a Guided Tour that takes you through the process of building and running an XOP.

Chapter 3 discusses the settings and techniques used with the Xcode and Visual C++ development systems. You need to read only the section that pertains you your development system.

Chapter 4 explains the basics of how Igor and XOPs interact.

After reading the first four chapters, you can select which of the remaining chapters you need to read depending on what your XOP is required to do.

Most XOP programmers will need to read Chapter 5, which explains how to add an external operation to Igor, or Chapter 6, which explains how to add an external function.

Chapter 7 explains how to access Igor data (data folders, waves and variables).

Chapters 8 through 13 discuss various topics such as adding menus, dialogs and help as well as multi-threading and 64-bit XOPs.

Chapter 14 discusses debugging and how to avoid bugs using solid coding practices.

Chapter 15 lists each of the XOP Toolkit routines available for you to call to interact with Igor or to perform other tasks.

If you are upgrading an XOP that was created with XOP Toolkit 7, we recommend that you read this chapter and then **XOP Toolkit 8 Upgrade Notes** on page 395. As explained there, we recommend that you leave your existing XOP project folders as they are and create new copies of those folders for further development using XOP Toolkit 8.

For a list of changes to the XOP Toolkit since version 8.00, see **XOP Toolkit 8 Release History** on page 405.

What is an XOP?

An XOP is a relatively small piece of C or C++ code that adds functionality to Igor Pro.

XOPs can be very simple or quite elaborate. A simple XOP might, for example, add an operation to Igor that applies a transformation to a wave. An elaborate XOP can add multiple operations, functions, menu items, and dialogs. It is even possible to build a data acquisition and analysis system on top of Igor.

"XOP" literally means "external operation". Originally XOPs were intended only to allow adding operations to Igor. Now an XOP can add much more so "XOP" has the meaning "external module that extends Igor". We sometimes call XOPs "extensions" or "Igor extensions".

Igor has two types of built-in routines: operations and functions. An operation (e.g., Display) has an effect but no direct return value. A function (e.g., sin) has a direct return value and, usually, no side effects. An XOP can add operations and/or functions to Igor Pro.

To create an XOP, you start by cloning a sample XOP project supplied by WaveMetrics. After modifying the clone, you compile it to produce the executable XOP.

An XOP contains executable code, required resources, and optional resources. The required resources tell Igor what operations and functions the XOP adds. The optional resources define things such as menu items, menus, and error messages.

When Igor Pro starts up, it looks for XOPs, as well as aliases or shortcuts that point to XOPs, in the Igor Extensions folder. For each XOP that it finds, it adds the operations, functions and menu items specified by the XOP's resources. When the user accesses an operation, function or menu item added by the XOP, Igor then communicates with the XOP using a simple protocol. The XOP can access Igor data and functions using a set of routines, called XOPSupport routines, provided with the XOP Toolkit.

Who Can Write an XOP?

In order to write an XOP you need to be very familiar with Igor concepts such as waves, command line operations, procedures and experiments.

Writing a simple XOP that just adds an operation or function to Igor requires advanced-beginner to intermediate programming skills. If you have less experience, you will need more patience.

Writing an elaborate XOP, especially one that adds dialogs, requires intermediate programming skills and some knowledge of graphical user interface programming.

A Brief History of Igor

Igor 1.0 was introduced in January of 1989 and ran on Macintosh computers which, at that time, used Motorola 680x0 processors (68K). Igor 1.0 did not support XOPs.

WaveMetrics released Igor 1.1 in March of 1989. Igor 1.1 supported external operations but not external functions. The first XOP Toolkit was also released at this time and supported development under MPW (Macintosh Programmer's Workshop) and Symantec THINK C. Igor 1.2 shipped in May of 1990 and also supported external operations but not external functions.

In March of 1994 WaveMetrics released Igor Pro 2.0, a major new version of Igor. This version added notebooks, control panels, drawing tools, and many other features, including user-defined functions. In April of 1994 WaveMetrics released XOP Toolkit 2.0 which supported XOP development under MPW and THINK C. It also supported external functions for the first time.

In May of 1995, WaveMetrics released Igor Pro 2.02, the first version optimized for Power Macintosh and its PowerPC processor (PPC). A version of the XOP Toolkit was released which supported development of PowerPC XOPs using MPW or the CodeWarrior development system from Metrowerks.

In February of 1996, WaveMetrics released Igor Pro 3.0. This version added multi-dimensional waves, text waves and data folders. XOP Toolkit 3.0 supported 68K and PPC development using MPW, THINK C, and CodeWarrior.

In November of 1997, WaveMetrics released Igor Pro 3.1. The main new thing in this version is that it ran under Windows 95 and Window NT 4.0 on Intel x86 processors as well as on Macintosh. XOP Toolkit 3.1 was released which supported development using CodeWarrior for 68K, PPC, and x86 development or Microsoft Visual C++ 5 for x86 development. Support for MPW and THINK C was dropped.

In September of 2000, WaveMetrics released Igor Pro 4.0. No new version of the XOP Toolkit was released.

In February of 2002, WaveMetrics released Igor Pro 4.05. This release included the Igor Pro Carbon application, the first version to run native on Mac OS X. It was based on Apple's Carbon API which supported software running on both Mac OS 9 and Mac OS X. Igor Pro 4.05 also included the pre-Carbon version of the application which ran on Mac OS 9 only.

In order to run native under Mac OS X, XOPs had to be revised to run under the Carbon API. In September of 2001, during the beta testing of Igor Pro Carbon, WaveMetrics released a Carbon XOP Toolkit which was shipped as part of XOP Toolkit 3.12.

In November of 2003, WaveMetrics shipped Igor Pro 5.0. For Macintosh, this release included just the Carbon version of Igor, not the pre-Carbon version. This meant that any Macintosh XOP that was to run with Igor Pro 5 had to be revised to use Apple's Carbon API. The Windows version of Igor Pro 5.0 required Windows 98, Windows ME, Windows 2000 or Windows XP. Support for Windows 95 and Windows NT was dropped.

From the XOP point of view, the major addition in Igor Pro 5 was a feature called "Operation Handler" – code within Igor that simplified the implementation of external operations and made it possible to call them directly from an Igor Pro user-defined function.

Igor Pro 5 was also the first version of Igor to support Mach-O XOPs. Mach-O is the binary format for an executable on Mac OS X. Previously Macintosh XOPs used the OS 9 CFM format.

In January of 2004, WaveMetrics released XOP Toolkit 5. It supported Macintosh development in CodeWarrior and Xcode and Windows development using Visual C++ 6, 7 (2003) and 8 (2005). The main new feature was Operation Handler support. It also supported pass-by-reference parameters with external functions.

Support for structure parameters was added in XOP Toolkit 5.04 in July, 2005.

In the spring of 2006, WaveMetrics released a beta version of Igor that ran native on Intel-based Macintosh computers. At the same time, XOP Toolkit 5.07 was released, adding support for Intel-based Macintosh XOPs.

In January of 2007, WaveMetrics released Igor Pro 6.0. No new version of the XOP Toolkit was released. Igor Pro 6.0 ran on MacOS 10.3.9 or later and on Windows 2000, Windows XP and Windows VISTA.

In June of 2009, WaveMetrics released Igor Pro 6.1. No new version of the XOP Toolkit was released. Igor Pro 6.1 ran on MacOS 10.4 or later and on Windows XP, Windows VISTA and Windows 7.

In August of 2010, WaveMetrics released Igor Pro 6.2 and XOP Toolkit 5.09. Igor Pro 6.2 ran on MacOS 10.4 or later and on Windows XP, Windows VISTA and Windows 7. In XOP Toolkit 5.09, documention related to obsolete technologies (e.g., Mac OS 9, CodeWarrior and Visual C++ 6) was removed.

Also in October of 2010, WaveMetrics released XOP Toolkit 6.00. XOP Toolkit 6 supported the creation of 64-bit Windows XOPs to run with the 64-bit Windows version of Igor. It required Igor Pro 6.00 or later. When running with Igor Pro 6.20 or later, an XOP created with XOP Toolkit 6 facilitated the creation of multi-threaded external operations and functions by allowing callbacks to Igor from an external operation or function called from an Igor thread, something that was not permitted before.

For XOP Toolkit 6, all sample source files were converted from C to C++. The programming techniques in the sample XOPs are still C techniques. The XOPSupport library remains C.

In February of 2013, WaveMetrics released Igor Pro 6.30 which ran on MacOS 10.4 or later and on Windows XP or later. That same month XOP Toolkit 6.30 was released. Sample projects and documentation for Visual

C++ 2012 were added. All sample XOPs were updated for compatibility with Xcode 4.6 and the LLVM compiler which Apple chose to replace the GCC compiler. This required source code changes which in turn require Igor Pro 6.20 or later.

In October of 2015, WaveMetrics released XOP Toolkit 6.40. This release added Xcode 6 and Visual C++ 2015 sample projects. It also added a new Igor7-compatible set of routines for supporting XOP menus.

In July of 2016, WaveMetrics released Igor Pro 7.00. Igor Pro 7 was a major overhaul of Igor Pro 6 and was built on the Qt cross-platform framework. Igor Pro 7 was available in both 32 bits and 64 bits and was the first version of Igor to run in 64 bits on Macintosh. Igor Pro 7 used UTF-8 text encoding, a form of Unicode, in place of system text encodings used by Igor Pro 6 and before.

Also in July of 2016, WaveMetrics released XOP Toolkit 7.00. XOP Toolkit 7.00 was the first toolkit that supported the creation of 64-bit Macintosh XOPs. XOPs created with XOP Toolkit 7.00 required Igor Pro 6.20 or later. The cross-platform dialog support of XOP Toolkit 6 was removed. The GBLoadWaveX XOP was added to show how to create a dialog using platform-specific code, replacing the old GBLoadWave XOP. The protocol for creating an XOP window was completely changed. As relates to text encoding, the XOP Toolkit 7 sample projects were optimized for use with Igor7, by virtue of using UTF-8 for source files.

Most pre-existing XOPs worked with Igor7. XOPs that add menus or dialogs need to be updated using XOP Toolkit 7. XOPs that added windows required extensive revision using XOP Toolkit 7. To create a 64-bit Macintosh XOP, you had to use XOP Toolkit 7.

In April of 2017, WaveMetrics released XOP Toolkit 7.01 which was tested in Xcode 7 and 8 and Visual C++ 2015 and 2017. XOP Toolkit 7.01 introduced new memory management routines described under **WM Memory XOPSupport Routines** on page 179. Use of these routines is required for compatibility with the 64-bit version of Igor Pro 8 on Macintosh and is recommended for all XOPs.

In May of 2018, WaveMetrics released Igor Pro 8.00. Igor8 supports object names up to 255 bytes in length. Object names in earlier versions of Igor were limited to 31 bytes. Igor8 supports old XOPs compiled with the 31-byte object name limit but generates an error if passing a long object name to the XOP is required. On Macintosh, Igor8 is available only in the 64-bit version, not in 32 bits. Consequently, existing 32-bit Macintosh XOPs can not run with Igor8. On Windows, Igor8 is available in both 64-bit and 32-bit versions, but 64 bits is recommended.

In June of 2018, WaveMetrics released XOP Toolkit 8.00 which was tested in Xcode 9 and Visual C++ 2015 and 2017. XOP Toolkit 8.00 supports long object names. Consequently, XOPs compiled using XOP Toolkit 8 require Igor Pro 8.00 or later. See **Choosing Which XOP Toolkit to Use** on page 5 for details.

Support for Xcode 10 was added in XOP Toolkit 7.03 and XOP Toolkit 8.01 in September of 2018. Xcode 10 supports 64-bit development only, not 32-bit development. The 32-bit targets in the Xcode project files were removed. They are not needed because there is no 32-bit MacOS version of Igor Pro 8 and XOPs created by XOP Toolkit 8 require Igor Pro 8 or later.

In August of 2021, WaveMetrics released Igor Pro 9.00 which is compatible with XOP Toolkit 8 XOPs.

In October of 2021, WaveMetrics released XOP Toolkit 8.02. The documentation and sample XOPs were updated for compatibility with Xcode 11, 12, and 13 and tested with Visual C++ 2015, 2017, and 2019. Thread safety was added to the VDT2 sample XOP. The manual chapter on adding windows to Igor was changed to reflect the fact that adding windows, except for text utility windows, is no longer possible.

XOP Toolkit 8

XOPs created with XOP Toolkit 8 require Igor Pro 8.00 or later.

The section **Igor/XOP Compatibility Issues** on page 67 explains how you can check which version of Igor you are running with. Your XOP should include a check that requires Igor Pro 8.00 or later.

If you are upgrading an XOP that was created with XOP Toolkit 7, we recommend that you read this chapter and then **XOP Toolkit 8 Upgrade Notes** on page 395. As explained there, we recommend that you leave your existing XOP project folders as they are and create new copies of those folders for further development using XOP Toolkit 8.

Choosing Which XOP Toolkit to Use

As of this writing (2021), WaveMetrics is shipping two versions of the XOP Toolkit - version 7 and version 8.

Use XOP Toolkit 7 if your XOP must run with Igor Pro 6 or Igor Pro 7, or if you are updating an older XOP that was never updated using XOP Toolkit 7.01 or later, or if you have not yet created a 64-bit version of your XOP.

Use XOP Toolkit 8 if you are writing a new XOP to target Igor Pro 8 or later, or if you are updating an XOP that was already updated using XOP Toolkit 7.01 or later to target Igor Pro 8 or later.

The next section explains the reason for these rules.

Main Issues

There are three main issues:

1. **64-bit XOPs**

   If you have not ported your existing XOP to 64 bits, use XOP Toolkit 7 to do that. Chapter 11 of the XOP Toolkit 7 manual includes detailed instructions for porting to 64 bits. To reduce clutter, the detailed instructions were removed from the XOP Toolkit 8 manual.

2. **Memory Management Routines**

   To support blocks of memory larger than 2 GB, WaveMetrics changed Igor's internal memory management routines for Igor Pro 8. No change is required for 32-bit Macintosh XOPs or for 32-bit or 64-bit Windows XOPs. However, to run with Igor Pro 8 or later, 64-bit Macintosh XOPs must be modified as explained under "WMMemory XOPSupport Routines" in Chapter 12 of the XOP Toolkit 7 manual.

   Although it is not required to update 32-bit Macintosh XOPs and 32-bit or 64-bit Windows XOPs, we recommend that you do so to keep your code up-to-date.

3. **Long Object Names and Paths**

   Prior to Igor Pro 8, object names, such as the names of waves, variables, and data folders, were limited to 31 bytes. In Igor Pro 8.00, this limit was raised to 255 bytes, and other limits were also raised. For compatibility with older XOPs, Igor Pro 8 and later can run with XOPs that do not support long names and paths, but return errors if passing a long name or path to the XOP is required.

   If your XOP uses any of the following constants then it uses object names and/or paths:

   MAX_OBJ_NAME, MAX_WAVE_NAME, MAX_DIM_LABEL_BYTES

   MAXCMDLEN, MAX_PATH_LEN

   XOP Toolkit 7 supports short names and paths only. It can create XOPs that run with Igor Pro 6.20 or later, but they will return errors if used with long names or paths in Igor Pro 8.00 or later.

   XOP Toolkit 8 supports long names and paths only. Long names and paths require Igor Pro 8.00 or later. Consequently, you should use XOP Toolkit 8 only if you are willing to require Igor Pro 8.00 or later. See **Long Names and Paths in XOPs** in Chapter 12 of the XOP Toolkit 8 manual for details.

Summary of Recommendations

If you are updating an XOP that was never updated using XOP Toolkit 7.01 or later, or if you have not yet created a 64-bit version of your XOP, first update your XOP using XOP Toolkit 7. See Appendix A in the XOP Toolkit 7 manual for details.

Once you have updated your XOP with XOP Toolkit 7, if you want to support long object names and paths and are willing to require Igor Pro 8.00 or later, update using XOP Toolkit 8. See Appendix A in the XOP Toolkit 8 manual for details.

Here is a summary of the rules for determining which XOP Toolkit to use:

- If you are creating a new XOP and you want to run with Igor Pro 8.00 or later, use XOP Toolkit 8.
- If you are creating a new XOP and you want to run with Igor Pro 6.20 or later, use XOP Toolkit 7.
- If you are updating an XOP created with XOP Toolkit 7.00 or before, or if you have not yet created a 64-bit version of your XOP, first update using the latest XOP Toolkit 7. Then, if you want to run with Igor Pro 8.00 or later, update using XOP Toolkit 8.

Macintosh and Windows XOPs

XOP Toolkit 8 supports development of 32-bit and 64-bit XOPs for both Macintosh and Windows. However, there is no 32-bit version of Igor Pro 8 for Macintosh so there is no point in compiling a 32-bit Macintosh XOP.

Most XOPs, by their nature, are platform-independent. For example, the code for a number-crunching XOP will be identical on all platforms. XOPs that have a user interface (menus, dialogs) or deal with files are partially platform-dependent. However, the XOP Toolkit provides routines for dealing with menus and files. Using these routines, it is possible to write most XOPs in a mostly platform-independent way. But XOPs still need to be compiled separately for each platform.

Development Systems

This table lists the development systems supported by XOP Toolkit 8.

Development System	**XOPs Run On**	**Dev Sys Files In**	**Notes**
Xcode 11, 12, 13	MacOS 10.11 or later	<project>/Xcode	
Visual C++ 2015, 2017, 2019	Windows 7 or later	<project>/VC	Any edition is OK.

Details on using each development system are provided in Chapter 3.

The sample projects will most-likely work with newer development system versions.

On Windows, the free Express Edition of Visual C++ is sufficient for most XOP development.

If you are an experienced programmer, you may be able to port the samples and the XOPSupport library to other development systems. You will need to read Chapter 3 to understand how XOP projects are constructed.

Activating XOPs Using the Igor Extensions Folder

In order for Igor to recognize and load an XOP, it must be "activated". You activate an XOP by putting it, or an alias (*Macintosh*) or shortcut (*Windows*) pointing to it, in the "Igor Extensions" or "Igor Extensions (64-bit)" folder.

There are Igor Extensions folders in the Igor Pro Folder but you should not use them to activate XOPs. Instead use the Igor Extensions folders in the "Igor Pro User Files" folder. These folders are created by Igor the first time you run the program.

The term "Igor Pro User Files" folder is generic. The actual folder name includes the Igor version, such as "Igor Pro 9 User Files".

This table shows the default location of the Igor9 Igor Extensions folders on each operating system:

OS	Path
MacOS	/Users/<user>/Documents/WaveMetrics/Igor Pro 9 User Files/Igor Extensions (64-bit)
Windows	C:\Users\<user>\Documents\WaveMetrics\Igor Pro 9 User Files\Igor Extensions
	C:\Users\<user>\Documents\WaveMetrics\Igor Pro 9 User Files\Igor Extensions (64-bit)

There is no 32-bit Macintosh version of Igor Pro 8 or 9.

You can display the Igor Pro User Files folder on the desktop by choosing Help→Show Igor Pro User Files while running Igor.

To activate an XOP, put the XOP, or an alias or shortcut pointing to it, in the "Igor Extensions" or "Igor Extensions (64-bit)" folder inside the "Igor Pro User Files" folder.

If you are activating a WaveMetrics XOP that resides in "Igor Pro Folder/More Extensions" or "Igor Pro Folder/More Extensions (64-bit)", make an alias or shortcut for the XOP and put the alias or shortcut in "Igor Pro User Files/Igor Extensions" or "Igor Pro User Files/Igor Extensions (64-bit)".

If you are activating your own XOP or a third-party XOP, you can put it directly in "Igor Pro User Files/Igor Extensions" or "Igor Pro User Files/Igor Extensions (64-bit)", or you can use an alias or shortcut if you prefer.

Installing the XOP Toolkit

The XOP Toolkit comes in a folder named "XOP Toolkit 8" which you can put anywhere on your hard disk.

The XOP Toolkit is delivered via electronic download only. You receive download instructions from WaveMetrics when you purchase the toolkit.

After downloading the XOP Toolkit, double-click the XOPToolkit8.dmg (*Macintosh*) or XOPToolkit8.exe (*Windows*) and install the "XOP Toolkit 8" folder on your hard disk.

All of the sample XOPs, the XOPSupport library and other support files are stored in a folder named IgorXOPs8 inside the "XOP Toolkit 8" folder.

Testing the Macintosh Installation

These instructions apply to Xcode 11 or later.

The instructions assume that you are running Igor8 or later and show how to build and activate the 64-bit version of the XOP and run it with the 64-bit version of Igor.

1. In the Finder, open the IgorXOPs8/XFUNC1/Xcode folder.
2. Open the XFUNC1.xcodeproj project in Xcode.
3. Choose File→Project Settings.
4. Click the Advanced button.
5. Click the Legacy radio button.
6. Click Done to close the Advanced Project Settings dialog.
7. Click Done to close the Project Settings dialog.
8. Choose Product→Scheme→XFUNC1-64.
9. Choose Product→Build.

   This creates the XFUNC1-64.xop package in the IgorXOPs8/XFUNC1/Xcode/build/Debug. Don't worry if you got some warnings from the compiler during the build.

10. Make an alias from the XFUNC1-64.xop package and drag the alias into your “Igor Extensions (x64)” folder.
11. Launch the 64-bit version of Igor.
12. Execute the following command:

    ```
    Print XFUNC1Add(3,4)
    ```
13. Igor should print "7" in the history area.

If Igor displayed an error message, make sure that you activated XFUNC1-64.xop correctly. See **Activating XOPs Using the Igor Extensions Folder** on page 6 for details. Also make sure that you ran the 64-bit version of Igor.

Testing the Windows Installation

These instructions apply to Visual C++ 2015, 2017, and 2019.

The instructions assume that you are running Igor8 or later and show how to build and activate the 64-bit version of the XOP and run it with the 64-bit version of Igor.

1. In the Windows desktop, open the IgorXOPs8\XFUNC1\VC folder.
2. Open the XFUNC1.sln file in Visual C++.
3. From the platform popup menu in the standard toolbar (under the menu bar), choose x64.
4. Choose Build Solution from the Build menu. This creates the XFUNC1-64.xop file in the IgorXOPs8\XFUNC1\VC folder. Don’t worry if you got some warnings from the compiler during the build.
5. Make a shortcut from the XFUNC1-64.xop file and drag the shortcut into your “Igor Extensions (x64)” folder.
6. Launch the 64-bit version of Igor.
7. Execute the following command:

    ```
    Print XFUNC1Add(3,4)
    ```
8. Igor should print "7" in the history area.

If Igor displayed an error message, make sure that you activated XFUNC1-64.xop correctly. See **Activating XOPs Using the Igor Extensions Folder** on page 6 for details. Also make sure that you ran the 64-bit version of Igor.

XOP Toolkit Overview

The XOP Toolkit includes a number of files that you will need to implement your XOP. The files are organized into folders all of which are in the IgorXOPs8 folder.

The IgorXOPs8 folder contains one folder for each of the sample XOPs, and an additional folder for the XOPSupport files, which are used by all XOPs.

The XOPSupport Folder

This XOPSupport folder contains

- Compiled XOPSupport libraries for the supported development systems.
- The C files and headers used to make those libraries.
- For Windows, the IGOR.lib and IGOR64.lib files which provides memory management and utility routines.
- Some miscellaneous files.

The main files of interest are listed in the following table. Your interaction with them will be mostly through including the XOPStandardHeaders.h file, linking with the library files, and calling the XOPSupport routines defined in the libraries. These routines are described in detail in Chapter 15.

File	What It Contains
XOPSupport.c	Utility and callback routines for communication with Igor.
XOPWaveAccess.c	Utility and callback routines for dealing with waves.
XOPStandardHeaders.h	Includes ANSI-C headers, Macintosh or Windows headers, and XOP headers. All XOP C and C++ files need to include this file.
XOPSupport.h	Declarations and prototypes for all XOPSupport routines. This file is included in XOPStandardHeaders.h.
XOP.h	#defines, data structures and global variable declarations used as part of the Igor/XOP communication protocol. This file is included in XOPStandardHeaders.h.
IgorXOP.h	#defines for Igor menu items, numeric type codes, and other items culled from Igor's own source code. This file is included in XOPStandardHeaders.h.
IgorErrors.h	#defines for Igor error codes. This file is included in XOPStandardHeaders.h.
/Xcode/libXOPSupport.a /Xcode/libXOPSupport64.a	The Xcode XOPSupport libraries for MacOS XOPs.
\VC\XOPSupport.lib \VC\XOPSupport64.lib	The Visual C++ 2015 XOPSupport libraries for Windows XOPs.
IGOR.lib IGOR64.lib	Allows a Windows XOP to call memory management and other utility routines that are implemented in the Igor.exe file on Windows.

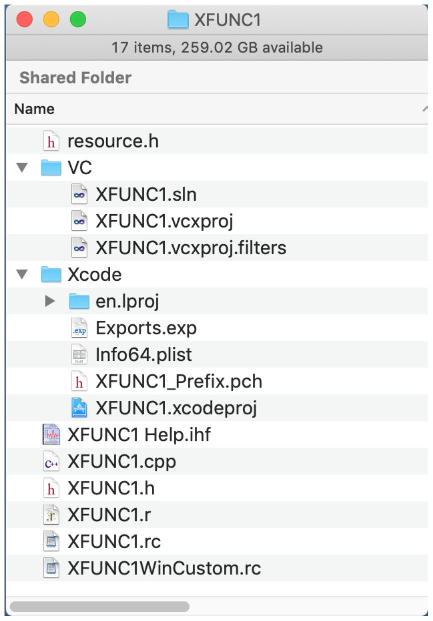
libXOPSupport.a, XOPSupport.lib and IGOR.lib are used when building 32-bit XOPs only.

libXOPSupport64.a, XOPSupport64.lib and IGOR64.lib are used when building 64-bit XOPs only.

In addition, the XOPSupport folder contains various header files and C files that deal with data folders, numeric conversions, menus, dialogs, windows, FIFOs, and file I/O.

Sample XOP Folders

Each sample XOP folder contains files that are used by all development systems and files that are development-system-specific. The development-system-specific files are grouped in their own folders. For example, here is a view of the XFUNC1 folder:



```
resource.h
▼ VC
    XFUNC1.sln
    XFUNC1.vcxproj
    XFUNC1.vcxproj.filters
▼ Xcode
  ▶ en.lproj
    Exports.exp
    Info64.plist
    XFUNC1_Prefix.pch
    XFUNC1.xcodeproj
XFUNC1 Help.ihf
XFUNC1.cpp
XFUNC1.h
XFUNC1.r
XFUNC1.rc
XFUNC1WinCustom.rc
```

Each sample XOP folder contains:

File	Example
A C++ file containing the code for the XOP.	XFUNC1.cpp
A header file containing #defines and other declarations.	XFUNC1.h
A resource file containing a text description of the XOP's resources.	XFUNC1.r (*Macintosh*) or XFUNC1.rc (*Windows*)
A "custom" resource file containing a text description of XOP-specific resources (*Windows* only)	XFUNC1WinCustom.rc
A resource header file containing defines used in the main resource file (*Windows* only)	resource.h
A help file. This is an Igor Pro notebook that has been formatted and opened in Igor Pro as a help file.	XFUNC1 Help.ihf
A "project", and/or "solution" file.	XFUNC1.xcodeproj (Xcode)
In Visual C++, open the solution file (.sln) to work with the project.	XFUNC1.sln (VC) XFUNC1.vcxproj (VC) XFUNC1.vcxproj.filters (VC)

When you compile an XOP, the compiler generates executable code from the C++ files. It then creates resources from the resource file. It writes the executable code and resources to the output executable XOP file on Windows or to the package on Macintosh. The projects are configured to store the compiled XOP in the development-system-specific folder (Xcode or VC).

XOPSupport

The XOPSupport folder contains the source code for the heart of the XOP Toolkit. These routines, described in detail in Chapter 15, are used by all XOPs. Most XOPs will use just a small fraction of the available routines. The routines are made available to the XOP by including XOPStandardHeaders.h and by linking with the XOPSupport library.

Callbacks are routines that execute code in Igor to perform services required by the XOP. There are callbacks for creating and manipulating waves and variables and for many other purposes.

Utilities are routines in the XOPSupport library itself that provide useful services without calling Igor. There are utilities for handling resources, files and other things.

Whether a particular XOPSupport routine is a callback or a utility is usually of no consequence to the XOP programmer.

Most callback routines are defined in the XOPSupport C files. They transmit parameters from the XOP to Igor and results from Igor back to the XOP. On Windows only, some callback routines call Igor directly. These routines are made available to the XOP by linking with IGOR.lib or IGOR64.lib. The callbacks that go directly to Igor have to do with Windows-specific functions (e.g., GetIgorClientHWND). Whether a particular callback goes through XOPSupport or goes directly to Igor is usually of no consequence to the XOP programmer.

The Sample XOPs

XOP1

XOP1 is the archetypal XOP. It adds a single operation to Igor. The name of the operation is also XOP1. The XOP1 operation expects the name of a single wave as its parameter. It adds the number 1 to each point in the wave. The wave must be either single or double-precision floating point.

XOP1 is a good starting point for very simple XOPs that add command line operations to Igor.

XFUNC1

XFUNC1 is a simple example of adding numeric functions to Igor Pro. It adds the XFUNC1Add(n1,n2) and XFUNC1Div(n1,n2) functions.

XFUNC1 is a good starting point for simple XOPs that add numeric functions to Igor Pro.

XFUNC2

XFUNC2 is a more complex example of adding numeric functions to Igor Pro. It adds the logfit(w,x) and plgndr(l,m,x) functions.

logfit is a function that can be used for curve fitting. It also illustrates passing a wave to an external function.

plgndr computes Legendre polynomials.

XFUNC3

XFUNC3 is a simple example of adding string functions to Igor Pro. It adds the xstrcat0(s1, s2) and xstrcat1(s1, s2) functions.

XFUNC3 illustrates receiving string parameters from Igor and returning string results.

MenuXOP1

MenuXOP1 is a simple XOP that illustrates the various ways that an XOP can add menus and menu items to Igor. It adds its own menu to Igor's main menu bar. This menu contains several submenus. It also adds a menu item to Igor's Misc menu and a menu item with a submenu to Igor's Analysis menu. MenuXOP1 also adds command line operations for enabling and disabling menu items and showing and hiding menus to illustrate how this is done. These operations are documented in the MenuXOP1.cpp file.

SimpleLoadWave

SimpleLoadWave is a simple file loader. It loads data from tab-delimited text files into Igor waves and is a good starting point for XOPs that import data into Igor. It adds one menu item and one operation to Igor. The menu item, Load Simple Delimited File, appears in Igor's Load Waves submenu. When the menu item is chosen, the SimpleLoadWave XOP puts up an Open File dialog allowing the user to select a plain text file to open. Then SimpleLoadWave opens the file, creates Igor waves and fills the waves with values from the text file. The XOP also adds the SimpleLoadWave operation to Igor. The user can invoke this operation from Igor's command line or from an Igor procedure to load tab-delimited text files.

SimpleLoadWave uses the file I/O routines provided by the XOPSupport library to achieve platform-independence.

GBLoadWaveX

GBLoadWaveX loads general binary files into Igor waves.

GBLoadWaveX is the descendent of the GBLoadWave XOP that was provided as a sample XOP in XOP Toolkit 1 through XOP Toolkit 6. In Igor7, GBLoadWave was built into Igor itself, so, in XOP Toolkit 7, the sample XOP was renamed GBLoadWaveX.

The GBLoadWaveX XOP adds the GBLoadWaveX command line operation to Igor and is a good starting point for XOPs that import binary data. It also illustrates how to create an Igor-style dialog using platform-dependent code.

SimpleFit

SimpleFit adds a simple curve-fitting function for fitting to a polynomial. The Guided Tour chapter of this manual shows how to compile SimpleFit and how to change it to fit a different function.

WaveAccess

WaveAccess illustrates three methods of accessing numeric wave data. One of the methods is optimized for speed but requires that you treat each numeric type separately. The other two methods are very easy to use with any numeric type and provide sufficient speed for most applications. WaveAccess also illustrates accessing Igor Pro text waves.

VDT2 ("Very Dumb Terminal")

VDT2 is an elaborate XOP that adds a dumb terminal emulator and command line operations for serial I/O to Igor as well as a submenu in Igor's Misc menu, a dialog and a window.

The VDT2 window is a text window implemented using the XOPSupport TU ("text utility") routines. When the user chooses VDT2 Settings from VDT2's submenu, VDT2 displays a dialog that allows the user to select the baud rate, serial port and other parameters. It stores these settings in Igor preferences and in experiment files. VDT2 supports sending and receiving text files via a serial port. It also allows the user to send or receive Igor waves and variables.

NIGPIB2

NIGPIB2 adds support for National Instruments GPIB cards to Igor. It adds no menu items, dialogs or windows but does add several powerful command line operations for controlling the GPIB and for transferring ASCII and binary data. NIGPIB2 is a good starting point for an XOP that interfaces Igor to hardware.

To compile NIGPIB2, you need some files from National Instruments. This is described in the file "About NIGPIB2.txt".

How Igor Integrates XOPs

When Igor Pro is launched, it searches the Igor Extensions folder and any sub-folders for XOPs and aliases (*Macintosh*) or shortcuts (*Windows*) that point to XOPs.

Macintosh XOPs are identified by the ".xop" extension in the name of the XOP package folder. Windows XOP files are identified by their ".xop" file name extension.

Igor first looks for an XOP's 'XOPI' ("XOP Information") resource which contains general information about the XOP. If this is missing, Igor displays an error message.

Next Igor looks for optional resources to determine what menus, menu items, operations and functions the XOP adds. Igor adds the menus to its main menu bar, adds menu items to its built-in menus, adds the operations to its list of operations, and adds the functions to its list of functions.

If an XOP adds functions, Igor loads the XOP into memory at launch time and keeps it there. If the XOP adds no functions then Igor does not load it until it is needed.

The user can access an XOP by selecting one of its menu items or by invoking one of its operations or functions. The XOP then communicates with Igor using the XOP protocol.

The XOP protocol is set up in a way that simplifies coding the XOP. At appropriate times, Igor sends a message to the XOP by calling its XOPEntry function. The XOP performs the action dictated by the message or ignores the message if it is not applicable.

The first time Igor calls the XOP, it calls the XOP's XOPMain function and passes to it a handle containing an IORec structure which holds all of the information that Igor and the XOP need to communicate. This handle, called an IORecHandle, is stored in a global variable by the XOPInit XOPSupport routine.

Among other things, the IORecHandle contains a message field which tells the XOP what it needs to do. You do not access the IORec structure directly. XOPSupport routines do this for you. The IORecHandle, like all handles passed between Igor and the XOP, is a Macintosh-style handle, even when running on Windows. (Macintosh-style handles are described under **Data Sharing** on page 67.)

XOP messages fall into several logical groups. The first message that every XOP receives is the INIT message. If the user chooses an XOP's menu item, Igor sends the MENUITEM message to the XOP. There are messages that allow the XOP to store its settings in the current Igor experiment file or to load settings from the experiment file. Finally, when the XOP is about to be closed, Igor sends it the CLEANUP message. The XOP can close its windows or do any other cleanup.

If your XOP is simple you can ignore most of these messages. An XOP that just adds an operation or function to Igor can ignore all messages except for INIT.

With three important exceptions, Igor always communicates with your XOP by passing a message to your XOPEntry routine. The exceptions are:

Event	**How XOP Is Called**
INIT message	Igor sends the INIT message by calling your XOPMain function.
Call external operation	Igor directly calls a C function that you designate (details in Chapter 5)
Call external function	Igor directly calls a C function that you designate (details in Chapter 6)

Once the XOP has received an applicable message it needs to do something. This sometimes requires calling Igor back to ask it to do something like create a wave or set the value of a variable. This is called a "callback". When the XOP does a callback, it passes the IORecHandle back to Igor. This time the handle contains a message for Igor requesting a service. You don't need to explicitly deal with the IORecHandle since the XOPSupport routines do it for you.

On Windows only, a few callbacks, mostly pertaining to memory management, go directly to Igor and do not use the IORecHandle.

Like XOP messages, callback messages fall into several categories. There are callbacks to access Igor waves and variables. There are callbacks to open a text window and to handle all of the things the user might do in the text window. There is a callback that allows an XOP to put a message (called a “notice”) in the history area of Igor’s command window. There are also callbacks that allow an XOP to execute a standard Igor command.

A simple XOP may use just a few callbacks.

The Basic Structure of an XOP

In very rough terms, you can think of your XOP program as shown in the following sketch which is best read from the bottom (high-level routines starting from XOPMain) to the top (low-level routines):

```
// Igor calls this directly for the corresponding external function
ExternalFunction()
{
   Process parameters
   Return result
}
// Igor calls this directly for the corresponding external operation
ExternalOperation()
{
   Process parameters
   Return result
}
XOPEntry()      // Igor sends most messages here
{
   Extract message from IORecHandle
   switch (message)
      Respond to message (often includes a callback to Igor)
   }
}
XOPMain()       // Igor sends the INIT message here
{
   initialize
}
```

Here is a more detailed sketch of a basic XOP program. In this example, the XOP adds an external operation and a menu item to Igor:

```
// XOP.cpp -- A sample Igor external operation

#include "XOPStandardHeaders.h"   // Include ANSI-C, Mac or Win headers,XOP headers
#includes specific to your XOP go here

static int
RegisterOperation()               // Register external operation with Igor
{
}

extern "C" int
ExecuteOperation()                // Service external operation
{
   Process parameters
   Return result
}

static int
MenuItem()                        // Handle selection of XOP's menu items if any
{
   Determine which menu item the user selected
   switch (menuItem) {
      Handle menu item
   }
}

static void
XOPQuit()
{
   Do any necessary cleanup before the XOP is closed.
}

extern "C" void
XOPEntry()                        // Called by Igor for all XOP messages after INIT.
{
   switch (GetXOPMessage()) {     // What message did we receive?
      case MENUITEM:              // The user selected the XOP's menu item
         MenuItem();
         break;

      Other cases here as needed

      case CLEANUP:
         XOPQuit();
         break;
   }
}

HOST_IMPORT int
XOPMain(IORecHandle ioRecHandle)  // First call from Igor goes here.
{
   XOPInit(ioRecHandle);          // Initialization common to all XOPs
   SetXOPEntry(XOPEntry);         // Set entry point for future messages

   XOP specific initialization
   RegisterOperation();           // Register external operation with Operation Handler

   return EXIT_SUCCESS;
}
```

Notice that Igor passes a parameter of type IORecHandle to the XOPMain function. This handle contains all of the information that Igor needs to communicate with the XOP.

The XOPInit(ioRecHandle) and SetXOPEntry(XOPEntry) calls in XOPMain are very important. Both of the called routines are defined in XOPSupport.c.

XOPInit stores the IORecHandle in a global variable for use by the other XOPSupport routines. This is the last time that you have to deal with the IORecHandle directly. From here on, the routines in XOPSupport deal with it for you.

SetXOPEntry sets a field in the IORecHandle that tells Igor the address of the function in the XOP to pass future messages to. XOPEntry is the function in every XOP's main C++ file that handles messages from Igor.

The RegisterOperation call tells Igor the address of the C function to be called for the external operation added by the XOP.

Preparing to Write an XOP

Before you write your XOP:

- Do the Guided Tour in Chapter 2
- Read the source code for XOP1 or XFUNC1
- Read Chapter 3 to learn how to build a project in your development system
- Read Chapter 4 to learn how Igor and your XOP interact

You write an XOP by cloning one of the sample XOPs and gradually modifying it. The cloning process is more than a simple folder duplication as illustrated in the guided tour.

Here are some other topics that you might need to know about after reading the chapters listed above.

Read **Data Sharing** on page 67 and **WM Memory XOPSupport Routines** on page 179 for information on memory management techniques.

If your XOP adds operations, functions or menu items to Igor, it might need to display its own error messages. See the section **XOP Errors** on page 59.

If your XOP adds an operation to Igor, read Chapter 5, **Adding Operations**.

If your XOP adds a function to Igor, read Chapter 6, **Adding Functions**.

If your XOP needs to manipulate waves, variables or data folders, read Chapter 7, **Accessing Igor Data**.

If your XOP adds menus or menu items to Igor, read Chapter 8, **Adding Menus and Menu Items**.

If your menu items summon dialogs, read **Adding Dialogs** on page 192.

If your XOP saves its settings or documents as part of an Igor experiment, read **XOPs and Experiments** on page 63.

To create a help file for your XOP, read Chapter 13, **Providing Help**.

Chapter 14, **Debugging**, discusses the most common sources of bugs, ways to find them, and ways to avoid them in the first place. Reading this chapter will probably save you a lot of time and aggravation.

Technical Support

WaveMetrics provides technical support via email. Before contacting us, you might want to check the following sources of information:

- The list of common pitfalls in Chapter 14

- The sample XOPs

Email Support

You can send questions to us via email at `support@wavemetrics.com`.

For sales matters, please use `sales@wavemetrics.com`.

World-Wide Web

Our Web address is `www.wavemetrics.com`.

Igor Mailing List

There is a mailing list of Igor users on the Internet. This is the best way to keep up with the latest Igor news. To join the list or search archives from the list, see:

`http://www.wavemetrics.com/support/mlist.htm`

IgorExchange

IgorExchange is a user-to-user support and collaboration forum hosted at wavemetrics.com:

`http://www.wavemetrics.com/forum`

If you create an XOP you might want to post it on IgorExchange for use by other Igor users.

Chapter 2

Guided Tour

Overview

This manual describes version 8 of the Igor XOP Toolkit which supports development using Xcode 11 or later on Macintosh and Visual C++ 2015, 2017 and 2019 on Windows.

XOP Toolkit 8 creates XOPs that run with Igor Pro 8.00 or later.

If your XOP must run with Igor Pro 6 or 7, or if you are updating an old XOP, you should use XOP Toolkit 7. See **Choosing Which XOP Toolkit to Use** on page 5 for details.

This guided tour gives a step-by-step example of creating a custom curve fitting external function using the SimpleFit project as a starting point. The tour consists of explanation interspersed with numbered steps for you to do.

The tour gives instructions for:

- Apple Xcode 11 or later on MacOS 10.14 or later
- Microsoft Visual C++ 2015, 2017 or 2019 (including the free “Community” edition)

Where the instructions are different for the different development systems, you will see steps identified as follows.

1-Xcode.

<Step for Xcode>.

1-Visual C++.

<Step for Visual C++>.

As explained under **Visual C++ Compatibility Issues** on page 45, you may get compile or link errors with another version of Visual C++.

During the tour, you will be instructed to restart Igor Pro several times because this is necessary when you recompile an XOP.

This guided tour assumes that you are using the 64-bit version of Igor Pro 8.00 or later.

Activating XOPs

In the guided tour, you will be instructed to activate an XOP multiple times. To activate a 64-bit XOP, put an alias or shortcut pointing to the XOP in the “Igor Extensions (64-bit)” folder inside“Igor Pro User Files” folder. For details, see **Activating XOPs Using the Igor Extensions Folder** on page 6.

What We Will Do

The SimpleFit project creates a single SimpleFit external function that can be used to fit to a polynomial. We will convert SimpleFit into a function called SimpleGaussFit that fits to series of Gaussian peaks. In doing this, you will see how to create an external function that fits to a function of your choice.

Installation

We assume you have already installed your development system, Igor Pro, and the XOP Toolkit.

Building SimpleFit

Before starting the modification of SimpleFit, we will build the original version to verify that the compiler and XOP toolkit installations are correct.

The SimpleFit folder is inside the IgorXOPs8 folder and contains the following project files:

Xcode/SimpleFit.xcodeproj	For Xcode.
	The compiled XOP will run on MacOS 10.11 or later.
VC\SimpleFit.sln	For Visual C++ on Windows.
	The compiled XOP will run on Windows 7 or later.

Building SimpleFit in Xcode

These steps were testing using Xcode 13.

1-Xcode.

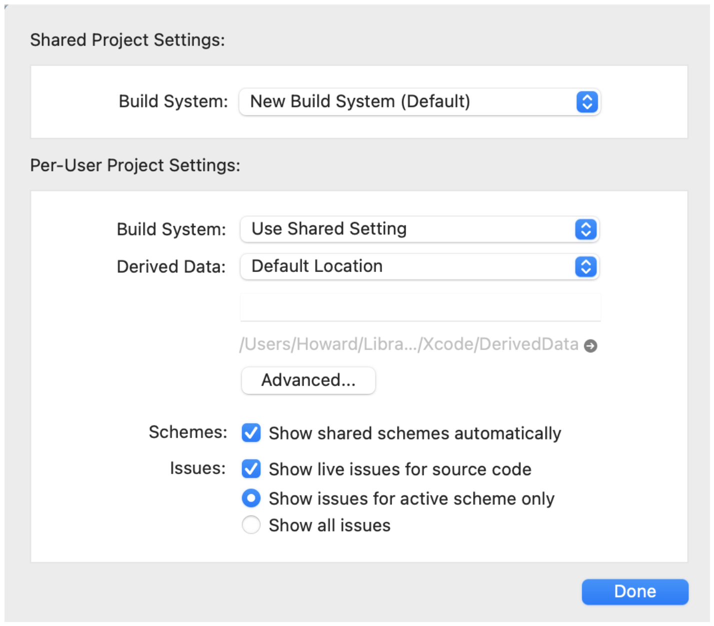
Open the SimpleFit/Xcode/SimpleFit.xcodeproj project file in Xcode.

The SimpleFit project window is shown.

Xcode may show a warning icon. If you click the warning icon, it may tell you about “updating to recommended settings”. Do not perform any updates as they may cause compile-time or run-time issues.

2-Xcode

Choose File→Project Settings to display the Project Settings dialog:



Shared Project Settings:

Build System: New Build System (Default)

Per-User Project Settings:

Build System: Use Shared Setting

Derived Data: Default Location

/Users/Howard/Libra.../Xcode/DerivedData

Schemes: [✓] Show shared schemes automatically

Issues: [✓] Show live issues for source code

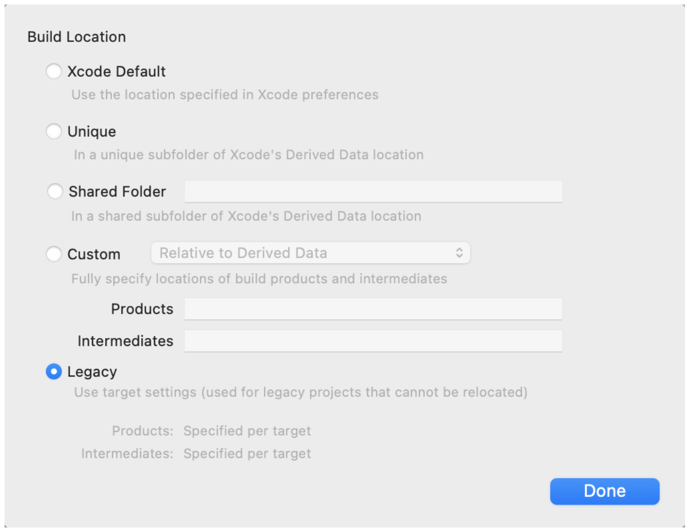
[✓ Show issues for active scheme only]

Show all issues

Although this dialog is called "Project Settings", Xcode stores these settings on a per-user basis. Consequently they must be set separately by each user and can not be preset in the XOP Toolkit sample XOPs.

NOTE: If you open other sample XOP Xcode projects in the future, or open this project while running as a different user, you need to remember to set these project settings.

Click the Advanced button to display the Advanced Project Settings dialog:



Build Location

Xcode Default

Use the location specified in Xcode preferences

Unique

In a unique subfolder of Xcode's Derived Data location

Shared Folder

In a shared subfolder of Xcode's Derived Data location

Custom Relative to Derived Data

Fully specify locations of build products and intermediates

Products

Intermediates

[✓ Legacy]

Use target settings (used for legacy projects that cannot be relocated)

Products: Specified per target

Intermediates: Specified per target

Click the Legacy radio button.

This causes the compiled XOP to be stored where we expect it, in the SimpleFit/Xcode/Debug folder.

NOTE: If you do not set the build location to Legacy your compiled XOP will be created in a strange location such as ~Developer/Xcode/Derived Data. So remember to set this setting for each XOP project you open in Xcode.

Click Done to close the Advanced Project Settings dialog.

Click Done to close the Project Settings dialog.

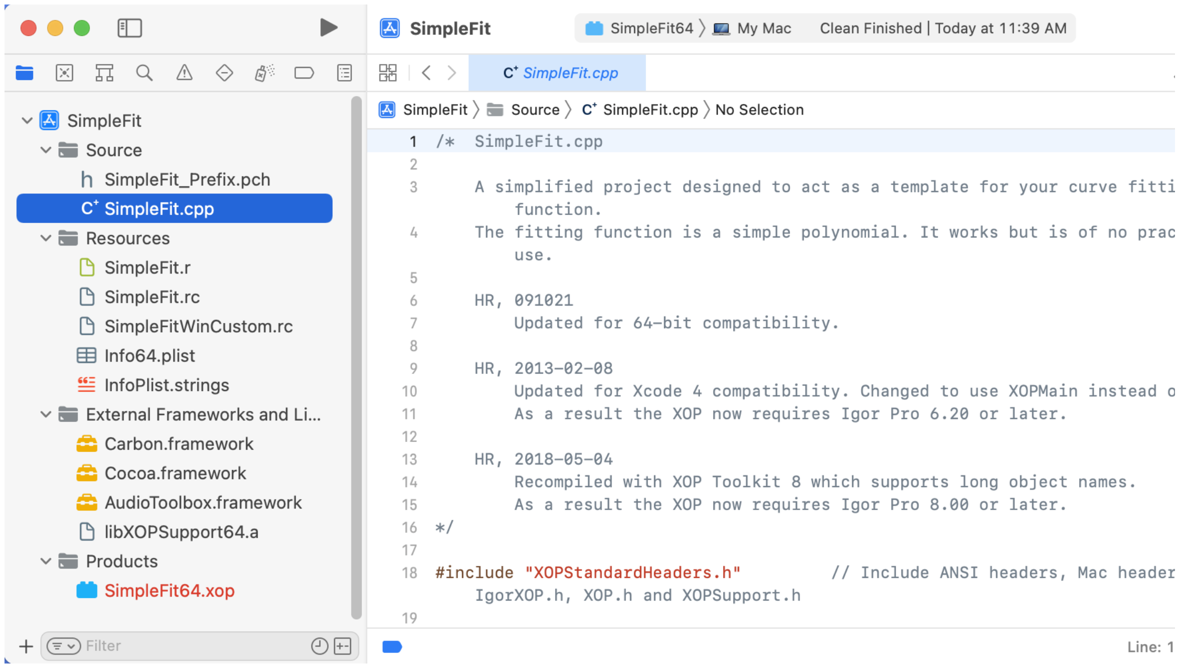
3-Xcode.

Choose View→Navigators→Project to display the project navigator pane. Open the disclosure triangles in the project navigator pane and select the SimpleFit.cpp file.

4-Xcode.

Choose Product→Scheme→SimpleFit64.

The project window should now look like this:



```
/*  SimpleFit.cpp

    A simplified project designed to act as a template for your curve fitti
        function.
    The fitting function is a simple polynomial. It works but is of no prac
        use.

    HR, 091021
        Updated for 64-bit compatibility.

    HR, 2013-02-08
        Updated for Xcode 4 compatibility. Changed to use XOPMain instead o
        As a result the XOP now requires Igor Pro 6.20 or later.

    HR, 2018-05-04
        Recompiled with XOP Toolkit 8 which supports long object names.
        As a result the XOP now requires Igor Pro 8.00 or later.
*/

#include "XOPStandardHeaders.h"         // Include ANSI headers, Mac header
    IgorXOP.h, XOP.h and XOPSupport.h

```

5-Xcode.

Choose Product→Build.

This is the same as choosing Product→Build For→Build For Running.

In a few seconds the compiler will finish and an XOP package named SimpleFit64.xop will be created in your SimpleFit/Xcode/build/Debug folder. Note where this is located for use in a upcoming step.

Don't worry if the compiler issues a few warnings.

6-Xcode.

Close the project window.

Building SimpleFit in Visual C++

1-Visual C++.

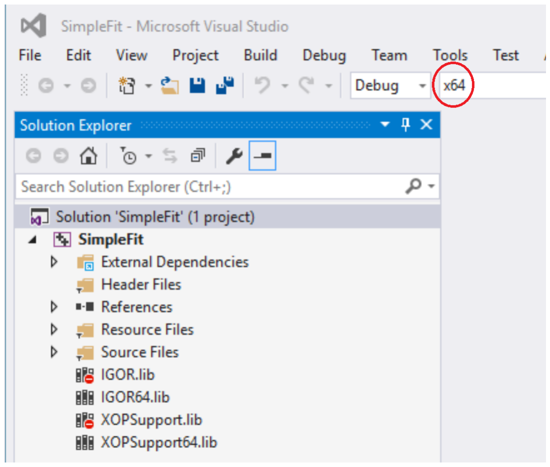
Open the solution file in SimpleFit\VC\SimpleFit.sln file in Visual C++.

The SimpleFit project window is shown.

Choose View→Solution Explorer and open the SimpleFit icon.

From the Solution Platforms popup menu, choose x64.

The window should now look like this:



2-Visual C++.

Choose Build→Build Solution.

In a few seconds the compiler will finish and an XOP file named SimpleFit64.xop will be created in your SimpleFit\VC folder. Note where this is located for use in a upcoming step.

Don't worry if the compiler issues a few warnings.

3-Visual C++.

Choose File→Close Solution.

Testing SimpleFit64

Now that we have built the SimpleFit64 XOP, our next task is to test it.

In the next step, we activate the SimpleFit64 XOP so that Igor will load it. For a detailed explanation of activating, see **Activating XOPs Using the Igor Extensions Folder** on page 6.

1. **On the desktop, make an alias (*Macintosh*) or shortcut (*Windows*) for the newly created SimpleFit64.xop and drag the alias or shortcut into the "Igor Extensions (64-bit)" folder.**

   You could drag the XOP itself instead of the alias or shortcut. We prefer to leave the XOP in the project folder while we are working on it.

2. **Back in the SimpleFit folder, make an alias (*Macintosh*) or shortcut (*Windows*) for the "SimpleFit Help.ihf" file and drag the alias or shortcut into the folder containing the just-compiled XOP. Make sure the alias or shortcut has the exact same name as the help file itself.**

   Igor looks for the help file in the folder containing the XOP itself (SimpleFit64.xop in this case). Normally the help file and the XOP reside in the same folder but this is not true during development. Igor will find the help file if you put an identically-named alias or shortcut to it in the same folder as the XOP.

3. **Launch the 64-bit version of Igor Pro.**

   The 64-bit version is named Igor64.app on Macintosh, Igor64.exe on Windows.

   You must restart Igor Pro after changing the contents of the "Igor Extensions (64-bit)"folder.

4. **Choose Command Help from the Help menu.**

   The Igor Help Browser appears with the Command Help tab selected.

5. **Find SimpleFit in the list of topics and select it.**

   The custom help for the SimpleFit external function is shown. This help is stored in the "SimpleFit Help.ihf" file.

6. **Follow the instructions in the help for exercising the function.**

This involves copying commands from the help and executing them in the Igor command line. You can also execute commands from a help file by selecting the command text and pressing Control-Enter (*Macintosh*) or Ctrl-Return (*Windows*) but this does not work in the Igor Help Browser.

7. **Quit Igor without saving.**

Creating a New Project

We now create a new project, SimpleGaussFit, by cloning the SimpleFit project. We will then change the SimpleGaussFit project to fit a Gaussian.

Cloning a project entails cloning the project folder and its contents: source files, resource files, help files and project files. In this case, here are the files:

SimpleFit File	SimpleGaussFit File	Description
SimpleFit.cpp	SimpleGaussFit.cpp	C++ file containing XOP source code
SimpleFit.r	SimpleGaussFit.r	Macintosh resource file
SimpleFit.rc	SimpleGaussFit.rc	Windows resource file
SimpleFitWinCustom.rc	SimpleGaussFitWinCustom.rc	Windows resource file containing XOP Toolkit-specific resources
resource.h	resource.h	Windows resource include file
SimpleFit Help.ihf	SimpleGaussFit Help.ihf	Igor help file
SimpleFit.xcodeproj	SimpleGaussFit.xcodeproj	Xcode project
SimpleFit.sln	SimpleGaussFit.sln	Visual C++ solution file
SimpleFit.vcxproj	SimpleGaussFit.vcxproj	Visual C++ project file
SimpleFit.vcproj.filters	SimpleGaussFit.vcproj.filters	Visual C++ project file

We use the “Create New XOP Project” Igor experiment, which you can find at the top level of the IgorXOPs8 folder, to clone a project.

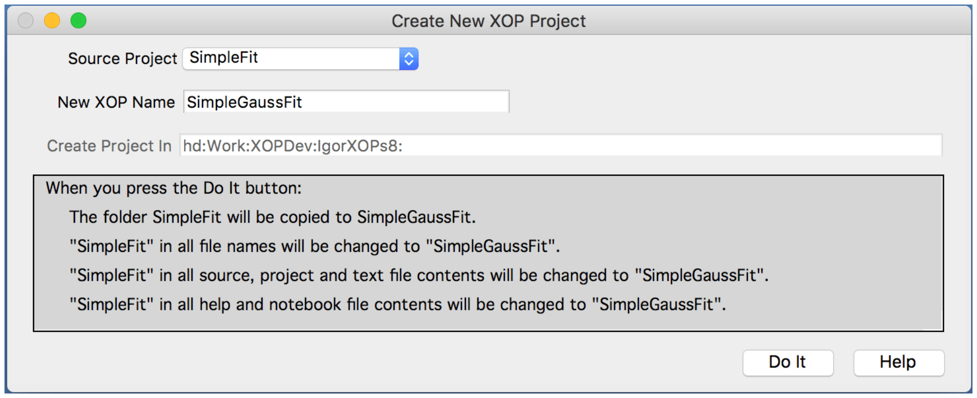
1. **On the desktop, locate your IgorXOPs8 folder.**
2. **Open the “Create New XOP Project.pxp” file in Igor.**

   The experiment opens and the Create New XOP Project panel appears.
3. **From the Source Project popup menu, choose SimpleFit.**
4. **In the New XOP Name textbox, enter SimpleGaussFit.**

   Double-check your spelling to make sure you have entered SimpleGaussFit exactly.

   Click in the panel outside of the New XOP Name textbox to finalize the setting.
5. **Verify that the Create Project In textbox contains the path to your IgorXOPs8 folder.**

   The panel should now look like this, though your path will be different. Note the text in the status area which explains what will happen when you click Do It.



Source Project: SimpleFit

New XOP Name: SimpleGaussFit

Create Project In: hd:Work:XOPDev:IgorXOPs8:

When you press the Do It button:
The folder SimpleFit will be copied to SimpleGaussFit.
"SimpleFit" in all file names will be changed to "SimpleGaussFit".
"SimpleFit" in all source, project and text file contents will be changed to "SimpleGaussFit".
"SimpleFit" in all help and notebook file contents will be changed to "SimpleGaussFit".

6. **Click the Do It button.**

   Create New XOP Project clones the SimpleFit folder, creating the SimpleGaussFit folder.

   In the clone, "SimpleFit" in all file names is changed to "SimpleGaussFit" and the contents of all source files, project files, text files, notebooks and help files are changed to replace "SimpleFit" with "SimpleGaussFit".

7. **Quit Igor without saving.**

8. **On the desktop, open the SimpleGaussFit folder and familiarize yourself with its contents.**

Building the New Project in Xcode

Before modifying the new project we will build it to verify that it was correctly created.

1-Xcode.

On the desktop, open the Xcode folder in the SimpleGaussFit folder.

This folder contains files specific to the Xcode development system.

2-Xcode.

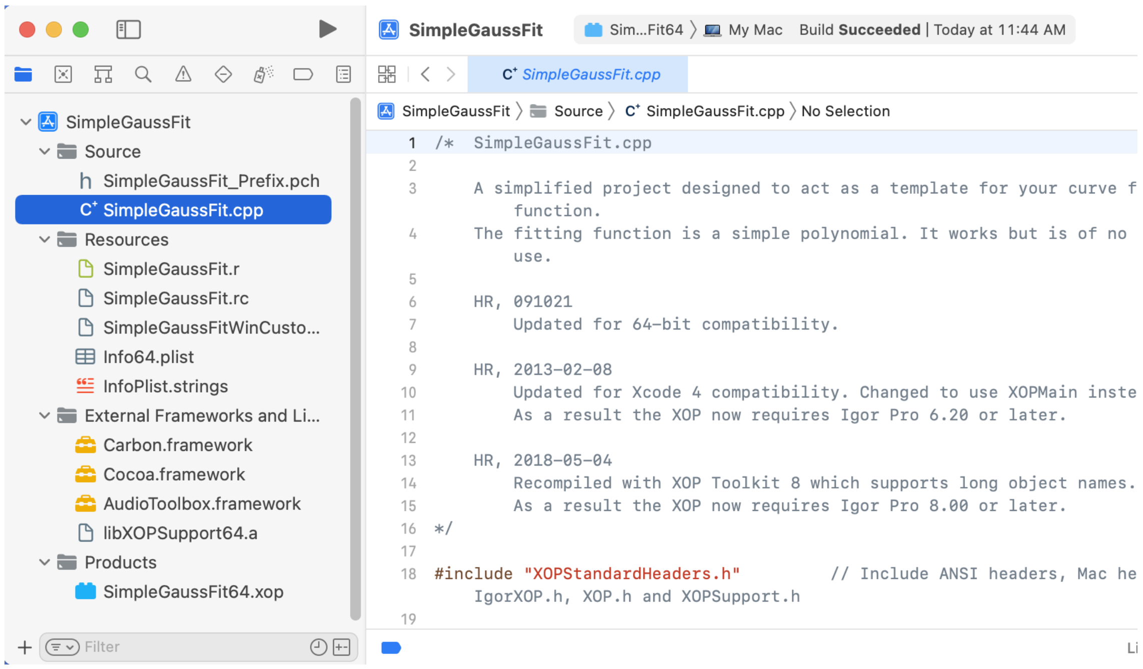
Open the SimpleGaussFit.xcodeproj file in Xcode.

Xcode may show a warning icon. If you click the warning icon, it may tell you about "updating to recommended settings". Do not perform any updates as they may cause compile-time or run-time issues.

3-Xcode.

Choose View→Navigators→Project to display the project navigator pane if it is not already visible. Open the disclosure triangles in the project navigator pane and select the SimpleGaussFit.cpp file.

The project window should now look like this:



```
/*	SimpleGaussFit.cpp

	A simplified project designed to act as a template for your curve f
		function.
	The fitting function is a simple polynomial. It works but is of no
		use.

	HR, 091021
		Updated for 64-bit compatibility.

	HR, 2013-02-08
		Updated for Xcode 4 compatibility. Changed to use XOPMain inste
		As a result the XOP now requires Igor Pro 6.20 or later.

	HR, 2018-05-04
		Recompiled with XOP Toolkit 8 which supports long object names.
		As a result the XOP now requires Igor Pro 8.00 or later.
*/

#include "XOPStandardHeaders.h"		// Include ANSI headers, Mac he
	IgorXOP.h, XOP.h and XOPSupport.h
```

4-Xcode.

Choose File→Project Settings to display the Project Settings dialog.

5-Xcode.

Click the Advanced button to display the Advanced Project Settings dialog and then click the Legacy button if it is not already selected.

NOTE: This step must be done any time you open a sample XOP project or your own XOP project if it was not previously opened in Xcode on your machine or if you open it as a different user.

6-Xcode.

Click Done to close the Advanced Project Settings dialog.

7-Xcode.

Click Done to close the Project Settings dialog.

8-Xcode.

Choose Product→Scheme→SimpleGaussFit64.

9-Xcode.

Choose Product→Build.

This is the same as choosing Product→Build For→Build For Running.

Xcode will build the project. You may get some warnings. When Xcode is finished, it should display a "Succeeded" message in the Activity Viewer section (top/center) of the Xcode main window.

10-Xcode.

On the desktop, verify that you have a package folder named SimpleGaussFit64.xop in IgorXOPs8/SimpleGaussFit/Xcode/build/Debug.

Debug is the name of the Xcode configuration currently being built so the output goes into the /build/Debug directory.

The SimpleGaussFit64.xop package folder is your compiled 64-bit XOP. It should look like a file in the Finder and you should have to Control-click it and choose Show Package Contents to see what it contains. Inside the package you will find a file named SimpleGaussFit64. This is the executable file.

11-Xcode.

Make an alias for the SimpleGaussFit64.xop package folder and put the alias in your "Igor Extensions (64-bit)" folder.

We now have a SimpleGaussFit64 XOP but it behaves just like the SimpleFit64 XOP. We will fix that in the following sections.

Building the New Project In Visual C++

1-Visual C++.

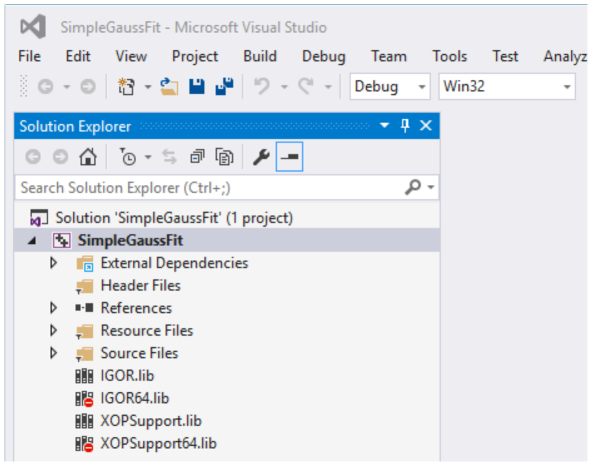
On the desktop, open the VC folder in the SimpleGaussFit folder.

This folder contains files specific to the Visual C++ development system.

2-Visual C++.

Open the SimpleGaussFit.sln file in Visual C++.

The SimpleGaussFit project window is shown:


SimpleGaussFit - Microsoft Visual Studio
File Edit View Project Build Debug Team Tools Test Analyz
Debug
Win32
Solution Explorer
Search Solution Explorer (Ctrl+;)
Solution 'SimpleGaussFit' (1 project)
SimpleGaussFit
External Dependencies
Header Files
References
Resource Files
Source Files
IGOR.lib
IGOR64.lib
XOPSupport.lib
XOPSupport64.lib

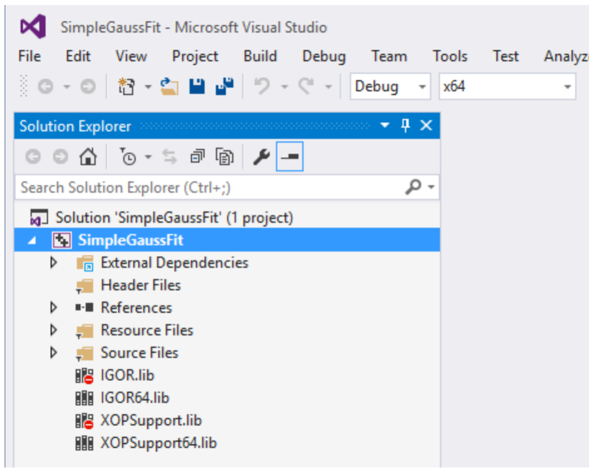
3-Visual C++.

If the icons in the Solution Explorer window are not open as shown above, click the icons to open them.

4-Visual C++.

From the Solution Platforms popup menu, choose x64.

The SimpleGaussFit project window now looks like this:


SimpleGaussFit - Microsoft Visual Studio
File Edit View Project Build Debug Team Tools Test Analyz
Debug
x64
Solution Explorer
Search Solution Explorer (Ctrl+;)
Solution 'SimpleGaussFit' (1 project)
SimpleGaussFit
External Dependencies
Header Files
References
Resource Files
Source Files
IGOR.lib
IGOR64.lib
XOPSupport.lib
XOPSupport64.lib

5-Visual C++.

Choose Build→Build Solution.

Visual C++ should build the XOP with no errors (though you may get some warnings), creating the file SimpleGaussFit64.xop in your IgorXOPs8\SimpleGaussFit\VC folder.

The warnings about XOPSupport.lib, if any, are generated because you are linking a non-debug library to the debug version of your XOP. This is not a problem.

6-Visual C++.

On the desktop, verify that you have a file named SimpleGaussFit64.xop in IgorXOPs8/Simple-GaussFit/VC.

This is the compiled XOP file.

7-Visual C++.

Make a shortcut for the SimpleGaussFit64.xop file and put the shortcut in your "Igor Extensions (64-bit)" folder.

We now have a SimpleGaussFit64 XOP but it behaves just like the SimpleFit64 XOP. We will fix that in the following sections.

Changing the Help

In this section, we modify the help that will appear for SimpleGaussFit in Igor Pro's Help Browser. This process consists of editing the help text in the "SimpleGaussFit Help.ihf" file.

The "SimpleGaussFit Help.ihf" file was created when the Create New XOP Project experiment cloned the "SimpleFit Help.ihf" file. The Create New XOP Project control panel replaced all occurrences in the help file of "SimpleFit" with "SimpleGaussFit". We now need to finish modifying "SimpleGaussFit Help.ihf".

1. **Launch the 64-bit version of Igor Pro.**
2. **Choose File→Open File→Notebook to display the Open File dialog.**

   We are opening the help file as a notebook so we can edit it.
3. **Select All Files from the file type popup menu in the Open File dialog.**
4. **Open the "SimpleGaussFit Help.ihf" file in the SimpleGaussFit folder.**
5. **Change the body of the help text to describe the SimpleGaussFit function.**

   Here is some suggested body text:

   > SimpleGaussFit is a curve fitting function for multiple Gaussian peaks.
   > The number of peaks is set by the length of the coefficient wave w. If w
   > contains four points then one peak will be generated as follows:
   >
   > `w[0] + w[1]*exp(-((x-w[2])/w[3])^2)`
   >
   > Add three additional coefficients for each additional peak by adding three
   > points to the coefficients wave.

   If this were a "real" project, we would provide more help with an example of how to use the external function.
6. **Save the notebook by choosing File→Save Notebook.**
5. **Close the notebook window. When Igor asks if you want to kill or hide it, click Kill.**

   Now we will compile the help file so that SimpleGaussFit will provide help in Igor's Help Browser.
8. **Choose File→Open→Help File and open the "SimpleGaussFit Help.ihf" file as a help file.**

   Igor will display a dialog asking if you want to compile the help file.

   Click the Yes button.

Next Igor will display a dialog saying that the help file has been compiled.

Click the OK button.

9. **Kill the help file by pressing the option key (*Macintosh*) or the Alt key (*Windows*) while clicking the help window's close box.**

   The help will appear in Igor's Help Browser after we have compiled and activated the SimpleGaussFit XOP.

10. **Quit Igor without saving.**

Changing and Compiling the Code

The SimpleGaussFit.cpp file was created when the Create New XOP Project experiment cloned the SimpleFit.cpp file. Create New XOP Project replaced all occurrences in the help file of “SimpleFit” with “SimpleGaussFit”.

If you were to compile the project right now you would create an external function named SimpleGaussFit but it would still act like SimpleFit. In this section, we modify the code to fit a Gaussian rather than a polynomial.

1. **In your development system, open SimpleGaussFit.cpp for editing.**
2. **Find the SimpleGaussFit function and make the following changes:**

   Change

```
double r,x;
```

   to

```
double r,x,t;
```

   Then, in the NT_FP32 case statement, change:

```
i = np-1;
r = fp[i];
for(i=i-1; i>=0; i--)
   r = fp[i] + r*x;
```

   to

```
r = fp[0];
for(i=1; i<np; i+=3) {
   t = (x-fp[i+1]) / fp[i+2];
   r += fp[i] * exp(-t*t);
}
```

   Carefully proofread the changes.

   Similarly, in the NT_FP64 case statement, change:

```
i = np-1;
r = dp[i];
for(i=i-1; i>=0; i--)
   r = dp[i] + r*x;
```

   to

```
r = dp[0];
for(i=1; i<np; i+=3) {
   t = (x-dp[i+1]) / dp[i+2];
   r += dp[i] * exp(-t*t);
```

```
    }
```

Carefully proofread the changes.

3. **Change the comments at the head of the function and at the top of the file such that they properly reflect the new code.**

   You can skip this step but it is what you should do when creating a real XOP.

4. **Save your changes to the SimpleGaussFit.cpp file.**

5-Xcode.

Choose Product→Scheme→SimpleGaussFit64.

Compile the project by choosing Product→Build.

The compile and link should proceed without errors (although you may get some warnings), creating SimpleGaussFit64.xop in the IgorXOPs8/SimpleGaussFit/Xcode/build/Debug folder. If you get errors, carefully check the changes that you made to the source code.

5-Visual C++.

Choose x64 from the Solution Platforms popup menu.

Compile the project by choosing Build→Build Solution.

The compile and link should proceed without errors (although you may get some warnings), creating SimpleGaussFit64.xop in the IgorXOPs8\SimpleGaussFit\VC folder. If you get errors, carefully check the changes that you made to the source code.

Testing SimpleGaussFit

Your external function, SimpleGaussFit, should now be functional. Let's test it.

1. **If it is running, quit Igor Pro.**

   Igor Pro scans XOPs at launch time and loads XOPs that add external functions into memory. So you must restart Igor when you change your XOP.

2. **In the SimpleGaussFit folder, make an alias (*Macintosh*) or shortcut (*Windows*) for the "SimpleGaussFit Help.ihf" file and drag the alias/shortcut into the folder containing the just-compiled XOP.**

   Make sure the alias or shortcut has the exact same name as the help file itself.

   Igor looks for the help file in the folder containing the XOP itself (SimpleGaussFit64.xop in this case). Normally the help file and the XOP reside in the same folder but this is not true during development. Igor will find the help file if you put an identically-named alias or shortcut to it in the same folder as the XOP.

3. **Restart the 64-bit version of Igor Pro.**

   Igor Pro will load the SimpleGaussFit function into memory.

4. **Choose Help→Command Help.**

5. **Find SimpleGaussFit in the list and select it.**

   The custom help for this external function is shown in the Help Browser. Igor gets the help from the "SimpleGaussFit Help.ihf" file which it looks for in the same folder as the SimpleGaussFit64 XOP. The help file does not need to be open for Igor to get operation or function help from it.

   If you don't see SimpleGaussFit in the list of functions:

   - Verify that you created an alias (*Macintosh*) or shortcut (*Windows*) from SimpleGaussFit64.xop and placed the alias or shortcut in the "Igor Extensions (64-bit)" folder. See **Activating XOPs Using the Igor Extensions Folder** on page 6 for details.
   - Make sure that you are running the 64-bit version of Igor, not the 32-bit version.
   - If you have multiple copies of Igor on your machine, make sure that you are running the copy you

intended to run by choosing Help→Show Igor Pro Folder.

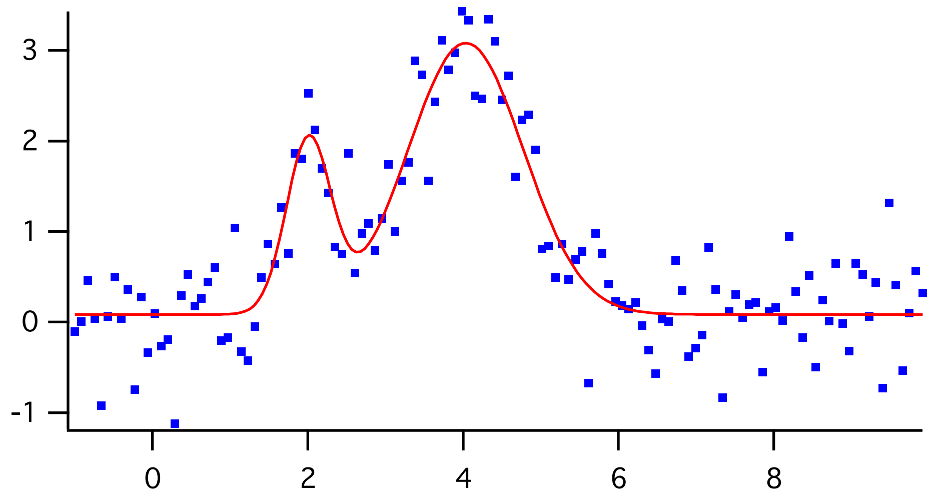
If you do see SimpleGaussFit in the list of functions but get a message saying help is not available when you select it:

- Verify that you created an alias (*Macintosh*) or shortcut (*Windows*) from the "SimpleGaussFit Help.ihf" help file and placed the alias or shortcut in the folder containing the XOP. The alias or shortcut must have the same name as the help file itself.
- Verify that you compiled the "SimpleGaussFit Help.ihf" file as directed in **Changing the Help** on page 28.

6. **Close the Help Browser.**
7. **Execute the following commands to exercise your external function with single-precision data:**

```
Make data; SetScale x,-1,10,data
data = 0.1 + gnoise(0.05)          // offset
data += 2*exp(-((x-2)/0.5)^2)      // first peak
data += 3*exp(-((x-4)/1.0)^2)      // second peak
Display data
ModifyGraph rgb=(0,0,50000), mode=2, lsize=3
Make coef = {0.1, 1.5, 2.2, 0.25, 3.8, 3.5, 0.5}
FuncFit SimpleGaussFit coef data /D
```

The result should look something like this:



If the fit doesn't converge or looks incorrect, carefully check the changes that you made to SimpleGaussFit.cpp and the commands that you executed in Igor.

To avoid errors due to arithmetic truncation it is best to use double-precision for curve fitting so now we will redimension to double-precision and redo the fit.

8. **Execute the following commands to exercise your external function with double-precision data:**

```
Redimension/D data, coef
coef = {0.1, 1.5, 2.2, 0.25, 3.8, 3.5, 0.5}
FuncFit SimpleGaussFit coef data /D
```

If the fit doesn't converge or looks incorrect, carefully check the changes that you made to SimpleGaussFit.cpp and the commands that you executed in Igor.

If you need to recompile the XOP, you will need to quit Igor Pro, recompile, and relaunch Igor Pro. This is necessary because Igor Pro loads the external function code into memory at launch time.

Touring the Code

In this section we take a very brief tour of the code to give you a sense of how an XOP works.

The details are explained in subsequent chapters. For now just try to get the big picture.

1. **In your development system, open the SimpleGaussFit.cpp file and scroll to the bottom until you see the XOPMain function.**

   In most sample XOP source files, the lower-level code appears at the top and the higher-level code at the bottom. It is usually easier to understand higher-level code, so we examine the higher-level code first.

   The XOPMain function for all XOPs is similar.

   XOPInit allows the XOPSupport library to initialize itself.

   SetXOPEntry tells Igor what function to call to pass messages to the XOP.

   Next comes a check to make sure that the current Igor version is not too old. XOPs created in XOP Toolkit 8 or later require Igor Pro 8.00 or later so every XOP should contain this check.

   SetXOPResult tells Igor the result of the call to the XOP's XOPMain function. 0 means "success".

   The function result (EXIT_FAILURE or EXIT_SUCCESS) is currently not used by Igor but may be used by a future version.

   If you had additional initialization to do, you would add it after the check of the Igor version. In XOPs that add an external operation, you will see a call to RegisterOperation at this point. SimpleGaussFit adds no external operations, just an external function.

2. **Scroll up until you see the XOPEntry function.**

   The SetXOPEntry call in the XOPMain function told Igor to pass subsequent messages to the XOPEntry function.

   The XOPEntry routine receives messages such as MENUITEM, IDLE, CLEANUP and many others from Igor. They are listed under **Basic XOP Messages** on page 55 but you don't need to know about that for now. XOPs can ignore messages that they don't care about. Most XOPs respond to just a few messages.

   XOPEntry has no function parameters because the message and its parameters are passed in a global handle. The function returns void because the XOP sends the result back to Igor via the same global handle by calling SetXOPResult. You don't access the global handle directly - the XOPSupport library accesses it for you when you call XOPSupport routines like SetXOPEntry, GetXOPMessage and SetXOPResult.

   Igor does not send messages to XOPEntry for external operation and external function calls but instead calls an XOP-supplied function directly.

   If the XOP defines an external function, as SimpleGaussFit does, during initialization Igor sends the FUNCADDRESS message once for each external function. The XOP responds by returning the address of the XOP function to call when that external function is invoked from an Igor command. In SimpleGaussFit, this is done with a call to RegisterFunction, defined just above XOPEntry.

3. **Scroll up until you see the SimpleGaussFit function.**

   This is the function that Igor calls when the SimpleGaussFit external function is invoked from an Igor command. Parameters to the external function are passed via a structure. This is explained in Chapter 6, **Adding Functions**.

   Next we will examine the resources that tell Igor what the XOP adds.

   At launch time, Igor examines each XOP's resources to determine what the XOP adds to Igor. Most XOPs add one or more external operations or external functions, or both. Most XOPs add error messages and some add menu items.

4-Xcode.

Open the SimpleGaussFit.r file.

The .r file on Macintosh contains standard Macintosh resources (e.g., vers, STR#) and XOP-specific resources (e.g., XOPC, XOPF).

4-Visual C++.

Open the SimpleGaussFit.rc file for editing as a text file by right-clicking it in Solution Explorer and choosing View Code.

The .rc file that appears in the Solution Explorer contains standard Windows resources (e.g., VERSION_INFO) only. XOP-specific resources (e.g., XOPC, XOPF) are stored in a separate .rc file that is referenced from the main .rc file.

Scroll to the bottom of the SimpleGaussFit.rc file until you see this line:

```
#include "SimpleGaussFitWinCustom.rc"
```

SimpleGaussFitWinCustom.rc contains the XOP-specific resources. They are what we are interested in at this point. We will now open SimpleGaussFitWinCustom.rc for editing as a text file.

Choose File→Open→File.

Navigate to the SimpleGaussFit folder.

Select SimpleGaussFitWinCustom.rc in the file list.

Click the down-arrow at the right edge of the Open button and choose Open With.

Select "Source Code (Text) Editor".

Click the OK button to open SimpleGaussFitWinCustom.rc for editing as text (not as a resource).

5. **Scroll down until you see the XOPF resource.**

   This resource tells Igor what external functions the XOP adds to Igor. In the case of SimpleGaussFit, just one external function is added. XOPs that add external operations would have an XOPC resource that serves a similar purpose.

6. **Scroll up until you see the XOPI resource.**

   This resource provides general information about the XOP to Igor. You do not need to change it.

7. **Scroll up until you see the STR# 1100 resource.**

   XOPs can define their own error codes. This resource provides the error strings for XOP error codes.

   More information about XOP resources is provided under **XOP Resources** on page 53.

Where To Go From Here

Read Chapter 3, **Development Systems** and Chapter 4, **Igor/XOP Interactions** in this manual.

If you plan to create an external operation, read Chapter 5, **Adding Operations**.

If you plan to create an external function, read Chapter 6, **Adding Functions**.

Find a sample XOP that would be a good starting point for your XOP and read that XOP's code.

Look at the chapter titles in the rest of this manual to see which chapters you will need to read.

Development Systems

Overview

XOP Toolkit 8 creates XOPs that run with Igor Pro 8.00 or later. It has been tested with Xcode 11 through 13 and with Visual C++ 2015 through 2019.

If your XOP must run with Igor Pro 6 or 7, or if you are updating an old XOP, you should use XOP Toolkit 7. See **Choosing Which XOP Toolkit to Use** on page 5 for details.

XOP Toolkit 8 includes sample XOPs and supporting files for the following development systems:

Development System	XOP Runs On	With Igor Version
Xcode 11 or later	MacOS 10.14 or later	Igor Pro 8.00 or later
Visual C++ 2015 through 2019	Windows 10 or later	Igor Pro 8.00 or later

On Windows, the free "Community Edition" of Visual C++ is sufficient for most XOP development.

The sample projects will most-likely work with newer development system versions.

If you use a newer version of Visual C++ on Windows, you may need to recompile the XOPSupport libraries and any other libraries to which you statically link, as explained under **Visual C++ Compatibility Issues** on page 45.

On Macintosh an XOP is a shared library. On Windows it is a dynamic link library (DLL). If you are an advanced programmer, you can probably figure out how to use other development systems.

The latest version of the XOP Toolkit is available for download from the same URL from which you originally downloaded the toolkit.

XOPs in Xcode

On Macintosh, XOP Toolkit 8 supports development using Xcode 11 or later. It has been tested with Xcode 11 through 13.

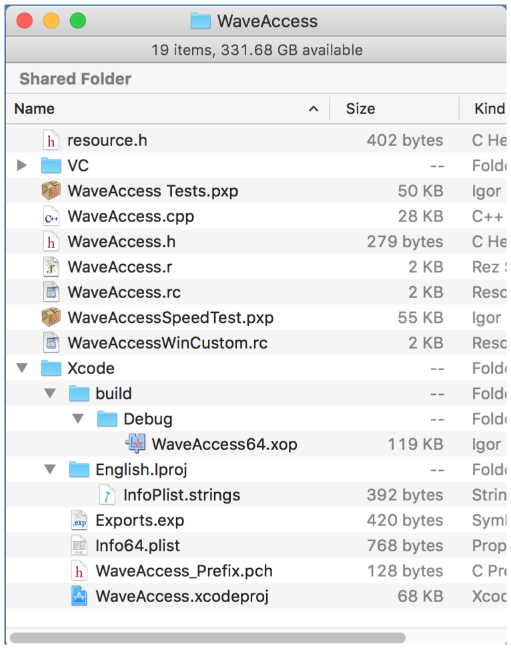
Each sample project contains an Xcode folder. The Xcode folder, e.g., WaveAccess/Xcode, contains the Xcode project file, e.g., WaveAccess.xcodeproj.

For instructions on converting an XOP Toolkit 7 project for use with XOP Toolkit 8, see **Xcode Project Changes For XOP Toolkit 8** on page 399.

XOP Projects in Xcode

This section provides the background information needed to understand how to create XOP projects in Xcode. For step-by-step instructions on creating a project, see **Creating a New Project** on page 24.

We will use the WaveAccess sample XOP as a case in point. The WaveAccess folder is inside the IgorXOPs8 folder and looks like this:



WaveAccess

19 items, 331.68 GB available

Shared Folder

Name	Size	Kind
resource.h	402 bytes	C He
▶ VC	--	Fold
WaveAccess Tests.pxp	50 KB	Igor
WaveAccess.cpp	28 KB	C++
WaveAccess.h	279 bytes	C He
WaveAccess.r	2 KB	Rez
WaveAccess.rc	2 KB	Reso
WaveAccessSpeedTest.pxp	55 KB	Igor
WaveAccessWinCustom.rc	2 KB	Reso
▼ Xcode	--	Fold
▼ build	--	Fold
▼ Debug	--	Fold
WaveAccess64.xop	119 KB	Igor
▼ English.lproj	--	Fold
InfoPlist.strings	392 bytes	Strin
Exports.exp	420 bytes	Syml
Info64.plist	768 bytes	Prop
WaveAccess_Prefix.pch	128 bytes	C Pr
WaveAccess.xcodeproj	68 KB	Xcoc

The Xcode project files are in the Xcode folder. The discussion assumes this arrangement and we recommend that you use it. Compiled XOPs are built in Xcode/build/Debug.

WaveAccess.xcodeproj is the project file and contains the project settings. (Actually it is a package folder, not a file.) The build folder contains data created by the compiler such as object code as well as the compiled XOP. The Xcode project includes a single 64-bit target named WaveAccess64. Since Igor Pro 8.00 and later run in 64 bits only on Macintosh, there is no need to build a 32-bit target.

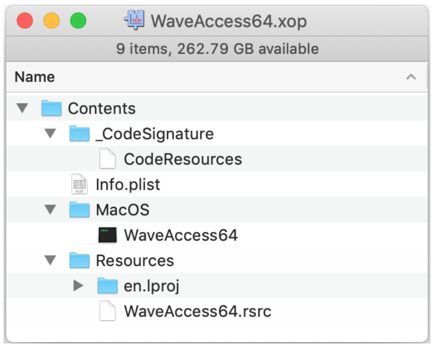
Igor Pro 8 and 9 run under the Intel architecture only, not under the ARM architecture. When running on an ARM machine, Igor Pro runs under Rosetta which supports Intel on ARM.

WaveAccess.cpp contains the project source code while WaveAccess.h contains the project headers.

WaveAccess.r contains the XOP's Macintosh resources. The use of this resource file is further explained under **XOP Resources** on page 53. The files resource.h, WaveAccess.rc and WaveAccessWinCustom.rc are used on Windows only.

The Exports.exp file is a plain text file that tells Xcode what routines the XOP needs to "export". In order for Igor to find a function in the XOP by name, it needs to be exported. The only function that needs to be exported for an XOP is XOPMain.

WaveAccess64.xop appears to be a file but is really a "package". If you control-click and choose Show Package Contents, you see what is inside:

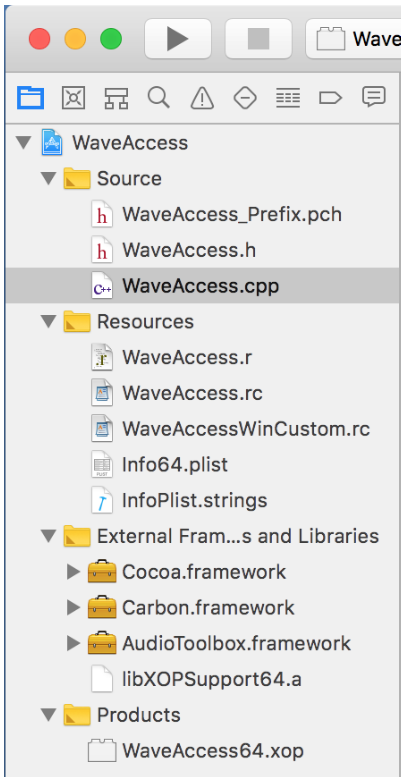


```
Contents
  _CodeSignature
    CodeResources
  Info.plist
  MacOS
    WaveAccess64
  Resources
    en.lproj
    WaveAccess64.rsrc
```

The layout of the package is as defined by Apple for a “packaged bundle”. Here “bundle” is Apple’s term for a plug-in.

The package is created automatically by Xcode when you compile the XOP. The actual executable code is in WaveAccess64. The other files contain data describing the package and resources. The Info.plist file in the package is a copy of the Info64.plist file from the project. The _CodeSignature folder is created by recent Xcode versions.

This Xcode screen shot of the project window shows the source files and libraries that are used in the project:



```
WaveAccess
  Source
    WaveAccess_Prefix.pch
    WaveAccess.h
    WaveAccess.cpp
  Resources
    WaveAccess.r
    WaveAccess.rc
    WaveAccessWinCustom.rc
    Info64.plist
    InfoPlist.strings
  External Fram...s and Libraries
    Cocoa.framework
    Carbon.framework
    AudioToolbox.framework
    libXOPSupport64.a
  Products
    WaveAccess64.xop
```

The WaveAccess_Prefix.pch file is automatically created by Xcode and used to speed up compilation by pre-compiling headers.

The Info64.plist file stores “meta-information” such as version information and the name of the executable file within the package folder.

The .framework files makes Apple APIs accessible to the XOP.

libXOPSupport64.a is the 64-bit XOPSupport library.

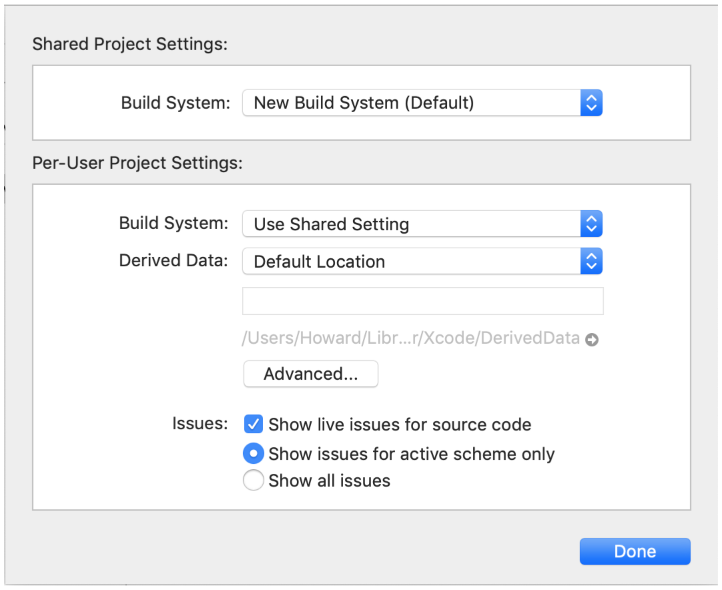
Xcode Project Settings

In Xcode, settings can be made at the project, target or configuration level. If no value is set for a given setting, it inherits the Xcode default value. For most settings it does not much matter whether they are set at the project level or at the target level.

Xcode has two additional kinds of settings: “project settings” and “schemes”. Confusing though it is, *project settings* are set via the File→Project Settings dialog while project *build* settings are set via the project navigator.

Xcode Project Settings Dialog

You access the Xcode Project Settings dialog by choosing File→Project Settings:



Shared Project Settings:

Build System: New Build System (Default)

Per-User Project Settings:

Build System: Use Shared Setting

Derived Data: Default Location

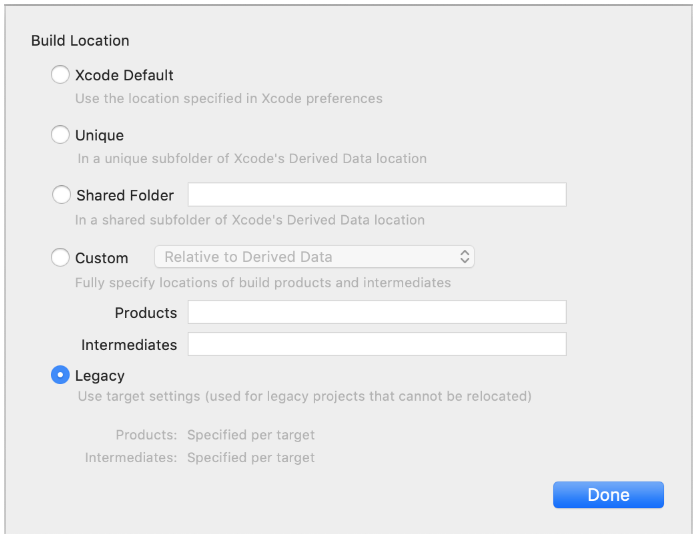
/Users/Howard/Libr...r/Xcode/DerivedData

Issues: ✓ Show live issues for source code

● Show issues for active scheme only

○ Show all issues

If you click the Advanced button, you get the following subdialog:



Build Location

○ Xcode Default
Use the location specified in Xcode preferences

○ Unique
In a unique subfolder of Xcode's Derived Data location

○ Shared Folder
In a shared subfolder of Xcode's Derived Data location

○ Custom Relative to Derived Data
Fully specify locations of build products and intermediates

Products

Intermediates

● Legacy
Use target settings (used for legacy projects that cannot be relocated)

Products: Specified per target
Intermediates: Specified per target

The *Build Location* setting should be set to “Legacy”. This causes the compiled XOP to be stored where we expect it, in the <project>/Xcode/Debug folder.

Xcode stores these settings on a per-user basis. Project settings set by one user are not accessible by another user. Consequently they can not be preset by WaveMetrics and must be set separately by each user.

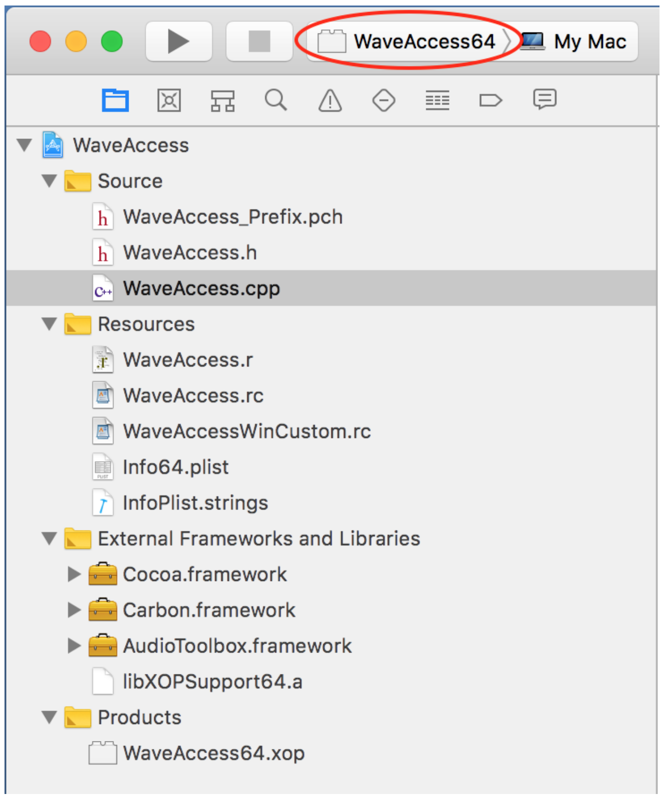
NOTE: If you do not set the build location to Legacy your compiled XOP will be created in a strange location such as ~Developer/Xcode/Derived Data. So remember to set this setting for each XOP project you open in Xcode.

NOTE: If you open any sample XOP Xcode project or open a project while running as a different user, you need to remember to set these project settings.

Alternatively, you can set these settings using Xcode preferences in which case they will be applied to any Xcode project that you open in Xcode for the first time as a given user. To do this, choose Xcode→Preferences, click the Locations icon, click the Advanced button, and click the Legacy radio button.

Xcode Schemes

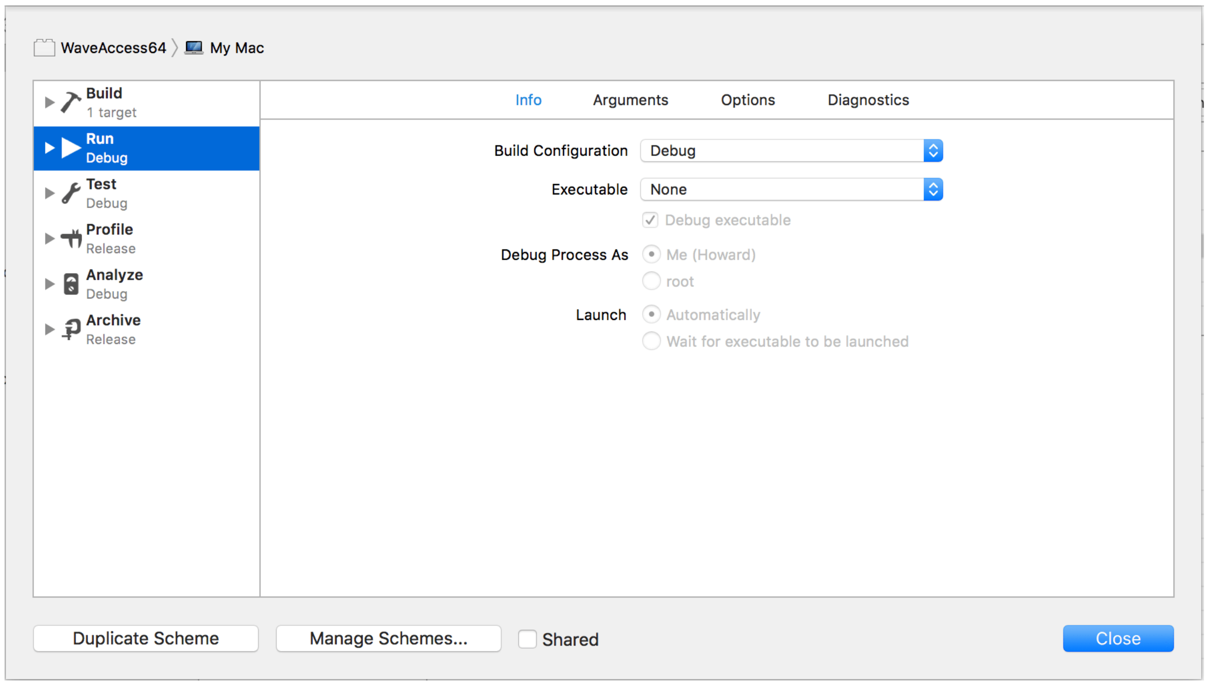
An Xcode *scheme* is a collection of settings that control things like which target (32-bit or 64-bit) to build, which configuration (debug or release) to build, and which application to run when you ask to debug the program. You choose which scheme to use through the Active Scheme popup menu in the top/left corner of the Xcode main window. Here the scheme name is shown as WaveAccess64:



If you don't see the Active Scheme popup menu, choose View→Show Toolbar.

Because of an Xcode bug, the Active Scheme popup menu may not appear, even with the toolbar showing. As an alternative, you can use the Product→Scheme submenu.

If you click the popup menu and choose Edit Scheme, you see this:


WaveAccess64 〉 My Mac

- Build — 1 target
- Run — Debug
- Test — Debug
- Profile — Release
- Analyze — Debug
- Archive — Release

Info | Arguments | Options | Diagnostics

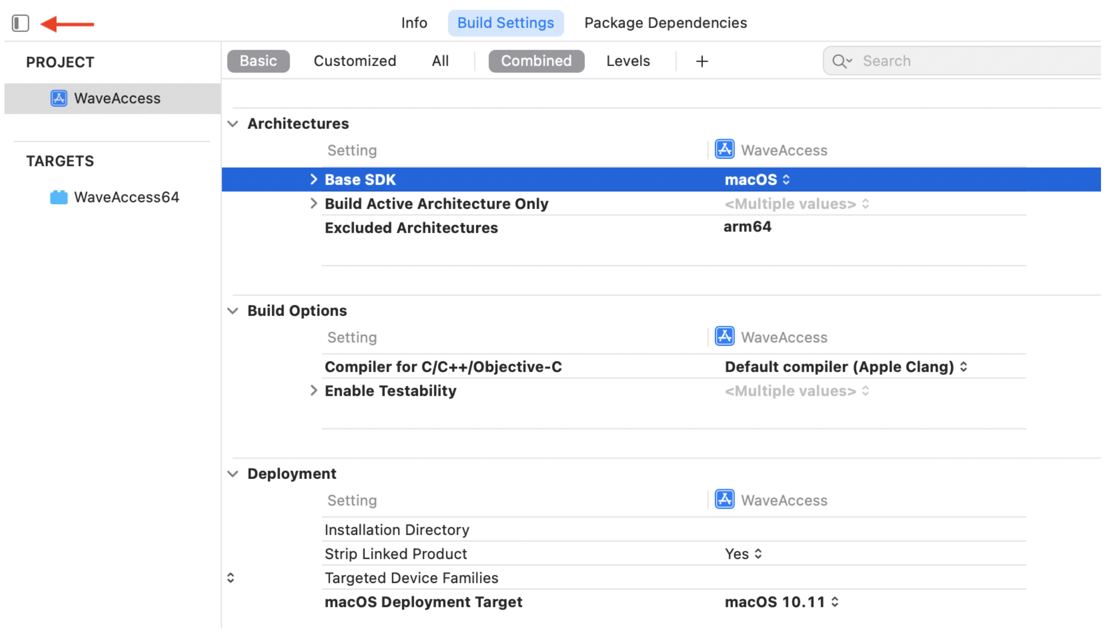
Build Configuration	Debug
Executable	None
	✓ Debug executable
Debug Process As	● Me (Howard)
	○ root
Launch	● Automatically
	○ Wait for executable to be launched

Xcode Project Build Settings

To display *project build* settings in Xcode, choose View⟶Navigators⟶Project (Show Project Navigator in Xcode 11 and before) and click the WaveAccess icon at the top of the project navigator. The project editor pane appears in the middle of the main Xcode window.

If you don't see the labels PROJECT and TARGETS, as shown below, click the Projects and Targets List button. This is the mysterious little rectangular icon with the solid little vertical rectangle running down its left side. In the screen dump below, we have added a red arrow pointing to this icon.

Click WaveAccess under the PROJECT heading. Click the Build Settings tab and the Basic and Combined buttons:



PROJECT
WaveAccess

TARGETS
WaveAccess64

Architectures

Setting	WaveAccess
Base SDK	macOS
Build Active Architecture Only	<Multiple values>
Excluded Architectures	arm64

Build Options

Setting	WaveAccess
Compiler for C/C++/Objective-C	Default compiler (Apple Clang)
Enable Testability	<Multiple values>

Deployment

Setting	WaveAccess
Installation Directory	
Strip Linked Product	Yes
Targeted Device Families	
macOS Deployment Target	macOS 10.11

Architectures

Base SDK: Set to MacOS or Latest MacOS in older Xcode versions.

Excluded Architectures: Set to “arm64”. This setting appears in Xcode 12.2 and later.

Build Options

Compiler for C/C++/Objective-C: Set to “Default compiler”.

Deployment

Mac OS Deployment Target: Set to MacOS 10.11 or later if 10.11 is not available.

Search Paths

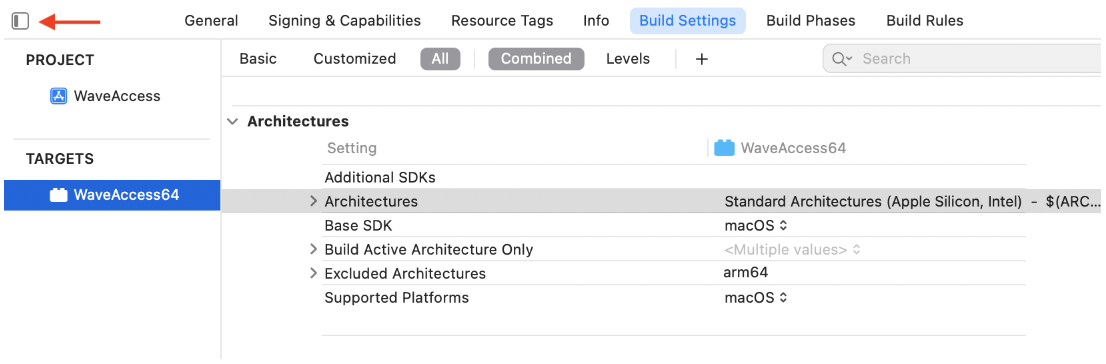
Always Search User Paths: Set to “No”.

Xcode Target Settings

To display *target* build settings in Xcode, choose View→Navigators→Project (Show Project Navigator in Xcode 11 and before) and click the WaveAccess icon at the top of the project navigator. The project editor pane appears in the middle of the main Xcode window.

If you don’t see the labels PROJECT and TARGETS, as shown below, click the Projects and Targets List button. This is the mysterious little rectangular icon with the solid little vertical rectangle running down its left side. In the screen dump below, we have added a red arrow pointing to this icon.

Click WaveAccess64 under the TARGETS heading. Click the Build Settings tab and the All and Combined buttons:



Architectures

Setting	WaveAccess64
Additional SDKs	
Architectures	Standard Architectures (Apple Silicon, Intel) - $(ARC...
Base SDK	macOS ◇
Build Active Architecture Only	<Multiple values> ◇
Excluded Architectures	arm64
Supported Platforms	macOS ◇

Architectures

Architectures: Choose “Standard Architectures”.

Base SDK: macOS (should be inherited from the project build settings).

Excluded Architectures: arm64 (should be inherited from the project build settings).

Packaging

Exported Symbols Files: Specified as “./Exports.exp”, meaning that Xcode is to look for the file Exports.exp in the project folder. Exports.exp declares the XOPMain function to be exported (i.e., visible to Igor Pro by name). This file will is the same for all XOPs.

Info.plist File: Set to Info64.plist.

Product Bundle Identifier: Set to com.wavemetrics.xop.waveaccess64.

Product Name: Set to WaveAccess64.

Wrapper Extension: Specified as “xop”. Igor identifies Mach-O XOP packages by the .xop extension on the package folder’s name.

Search Paths

Always Search User Paths: Set to “No”.

Header Search Paths: Set to “../../XOPSupport”. This allows #include statements to find the XOPSupport header files. The path is relative to the folder containing the .xcodeproj project file.

Library Search Paths: Set to “../../XOPSupport/Xcode”. This allows the Xcode version of the XOPSupport library to be found.

Apple Clang - Language

Prefix Header: This is automatically set by Xcode to “WaveAccess_Prefix.pch” when the project is created. Xcode automatically creates this file. The file determines which header files are pre-compiled and stored in binary form with the project data to speed up compilation.

Apple Clang - Warnings

Deprecated Functions: We turn this warning off. You can turn it on if you decide to update your code to use all of the latest functions.

Other Warning Flags: Set to “-Wno-parentheses”. This turns off warnings for assigning the result of a function call to a variable in a conditional statement, such as:

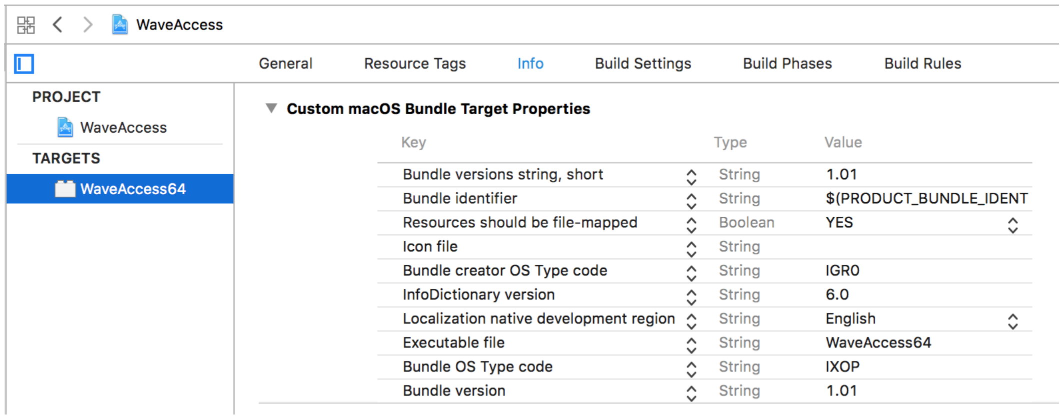
```
    if (err = SomeFunction())
```

Rez - Language

OTHER_REZFLAGS: Set to “-i ../../XOPSupport”. This specifies flags to pass to the Rez compiler when the .r file is compiled. It allows #include statements to find the XOPStandardHeaders.r file in the XOPSupport folder.

Xcode Target Info

To display *target info* settings in Xcode, choose View→Navigators→Project (Show Project Navigator in Xcode 11 and before) and click the WaveAccess icon at the top of the project navigator. The project editor pane appears in the middle of the main Xcode window. Click WaveAccess64 under the TARGETS heading. Click the Info tab:



Key	Type	Value
Bundle versions string, short	String	1.01
Bundle identifier	String	$(PRODUCT_BUNDLE_IDENT
Resources should be file-mapped	Boolean	YES
Icon file	String	
Bundle creator OS Type code	String	IGR0
InfoDictionary version	String	6.0
Localization native development region	String	English
Executable file	String	WaveAccess64
Bundle OS Type code	String	IXOP
Bundle version	String	1.01

These settings are written to the project’s Info64.plist file which Xcode copies to the Info.plist file in the XOP package folder when the XOP is compiled.

The values in Info64.plist can be superceded by the InfoPlist.strings file in the en.lproj folder for localization. If values that you enter in the Properties tab do no take effect when the XOP is compiled, check the InfoPlist.strings file and manually update it if necessary.

Executable File: Set to the name of the executable file in the XOP package. For the WaveAccess64 XOP, the package name is WaveAccess64.xop and the executable file, named WaveAccess64, is located in the WaveAccess64.xop package at Contents/MacOS/WaveAccess64.

When Igor loads your XOP, if you get an error such as "Can't load the executable file in the XOP package", you may have an inconsistency in your settings. The Executable File setting must match the target product name setting under Packaging in the target build settings. This is explained further under **Check Your Info.plist File** on page 222.

Bundle Identifier: Set to $(PRODUCT_BUNDLE_IDENTIFIER) which means that the identifier is taken from the Product Bundle Identifier setting in the Packaging section of the target build settings. The bundle identifier is a unique string associated with an executable. By convention it uses Java package notation like com.wavemetrics.xop.waveaccess64. For your own XOPs you can make up an identifier of your choice.

Bundle OS Type Code: Set to IXOP. This is necessary for the XOP package to be displayed in the Finder using the correct icon for an XOP.

Bundle Creator OS Type Code: Set to IGR0. This associates the XOP with the Igor Pro application.

Bundle Version and Bundle Version String: Set the version for the XOP package. This is the version reported by the Finder. It can be overridden by the InfoPlist.strings file in the en.lproj folder.

Xcode SDKs

An SDK (software development kit) is a set of libraries, header files and other components needed to build an executable on MacOS. Apple releases a new SDK with each operating system release. The new SDK adds support for new system routines and sometimes removes support for old system routines.

In each Xcode project you specify the SDK that you want to use via the Base SDK setting in the project build settings. In Xcode 11 and later, this is set to macOS and refers to

```
Xcode.app/Contents/Developer/Platforms/MacOSX.platform/Developer/SDKs/MacOSX.sdk
```

which is the SDK shipped with whichever version of Xcode you are using.

Converting to the LLVM Compiler

Prior to XOP Toolkit 6.30 the sample XOP projects were configured to use the GCC compiler. Apple dropping support for the GCC compiler in favor of the LLVM compiler. Consequently in XOP Toolkit 6.30 all sample projects were converted to use LLVM.

If you are updating an old project, you will need to set it to use the LLVM compile as explained under **Xcode Project Build Settings** on page 40.

You also may need to convert your XOP to use XOPMain as its main function. See **The XOPMain Function** on page 179 for details.

Updating Xcode Projects

For instructions on updating XOP Toolkit 7 or 8 projects to the current version of Xcode, see **Xcode Project Changes For XOP Toolkit 8** on page 399.

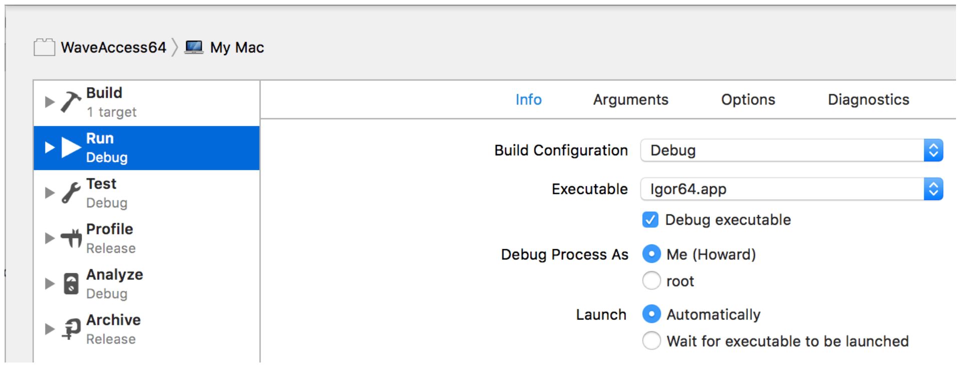
Debugging an XOP in Xcode

You need to tell Xcode what program hosts your XOP. Here's how you would do this after opening the WaveAccess sample project in Xcode:

1. Choose Product→Scheme→Edit Scheme.
2. From the popup menu in the top/left corner of the window, choose WaveAccess64.

3. Click Run in the list of actions on the left.
4. Click the Info tab.
5. Choose Debug from the Build Configuration popup menu.
6. Click the Executable popup menu, choose Other to display the Choose File dialog.
7. Select your Igor Pro application file, Igor64.app, and click the Choose button.

   The scheme editor window should now look like this:



Build Configuration: Debug

Executable: Igor64.app

✓ Debug executable

Debug Process As: ● Me (Howard) ○ root

Launch: ● Automatically ○ Wait for executable to be launched

8. Click Close.
9. Choose Product→Build.

   This is the same as choosing Product→Build For→Build For Running.

   When the project compilation is finished, go into the Finder and find the compiled XOP (e.g., /WaveAccess/Xcode/build/Debug/WaveAccess64.xop).
10. On the desktop, make an alias for that XOP and activate it as described under **Activating XOPs Using the Igor Extensions Folder** on page 6.
11. In Xcode, open the your main source file (e.g., WaveAccess.cpp) and set a breakpoint at the start of the XOPMain function. Click in the left-hand gutter to set the breakpoint.
12. In Xcode choose Product→Run.

    Xcode will launch Igor Pro.
13. If your XOP adds one or more external functions, Igor will launch it at this time, in which case you should break into Xcode at the point in the XOPMain function where you set the breakpoint.
14. If your XOP does not add external functions, do something to cause Igor to launch it, such as invoking your external operation from Igor's command line. You should break into Xcode at this point.

Signing and Notarizing an XOP in Xcode

Starting with Mac OS 10.15, Apple introduced increasingly strict security requirements on executable code, including XOPs. Executables that a user downloads or receives as an email attachment must be signed and notarized or Mac OS refuses to run them. As of this writing (October 2021, Mac OS 12.0), you can still run XOPs that you compile on your own machine or that you transfer across a local area network without signing and notarizing them.

All WaveMetrics XOPs that ship with Igor Pro 8.04 and later are signed and notarized and should therefore load properly.

As of this writing (October 2021, Mac OS 12.0.1), users can override the Mac OS security requirements for downloaded XOPs using a workaround explained at https://www.wavemetrics.com/forum/general/workaround-catalina-xop-problem

If you develop XOPs for use by others you can provide a smooth user experience by signing and notarizing your XOP. However, this is a complicated process. You have to join the Apple Developer program, obtain a certificiate from Apple, and use Xcode or command line tools to sign and notarize your XOP.

If you develop XOPs for use by others and would like documentation about signing and notarization of XOPs, send an email to WaveMetrics support requesting the "Signing and Notarization of Macintosh XOPs" help file.

XOPs in Visual C++

On Windows, XOP Toolkit 8 supports development using Visual C++ 2015, Visual C++ 2017 and Visual C++ 2019. It will likely work with later versions of Visual C++, but see the caveats in the next section.

The community (free) edition of Visual C++ is fine for most 32-bit and 64-bit XOP development.

Each sample project contains a VC folder. The VC folder, e.g., WaveAccess/VC, contains the Visual C++ solution file, e.g., WaveAccess.sln.

For instructions on converting an XOP Toolkit 7 project for use with XOP Toolkit 8, see **Converting Your Older Visual C++ Project** on page 403.

Visual C++ Compatibility Issues

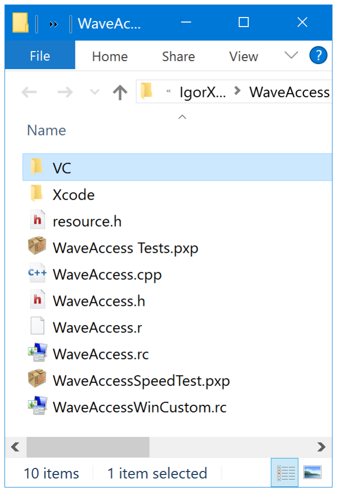
Microsoft's "Breaking Changes in Visual C++ 2015" document (https://msdn.microsoft.com/en-us/library/bb531344.aspx) warns against mixing code (applications and static or dynamic libraries that they call) compiled with different versions of Visual C++. Mixing can cause arcane compilation and linking errors as well as runtime errors. These compatibility requirements cause serious headaches when moving to a new version of Visual C++.

However, Microsoft's release notes indicate that Visual C++ 2015, 2017, and 2019 are compatible and we have not seen problems from building in Visual C++ 2017 and 2019 using the Visual C++ 2015 version of the XOPSupport library.

XOP Projects in Visual C++

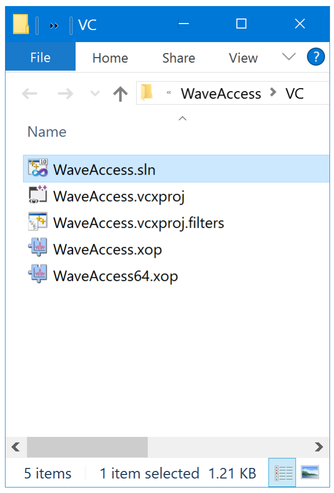
This section provides the background information needed to understand how to create XOP projects in Visual C++. For step-by-step instructions on creating a project, see **Creating a New Project** on page 24.

We will use the WaveAccess sample XOP as a case in point. The WaveAccess folder is inside the IgorXOPs8 folder and looks like this:



VC
Xcode
resource.h
WaveAccess Tests.pxp
WaveAccess.cpp
WaveAccess.h
WaveAccess.r
WaveAccess.rc
WaveAccessSpeedTest.pxp
WaveAccessWinCustom.rc

10 items   1 item selected



WaveAccess.sln
WaveAccess.vcxproj
WaveAccess.vcxproj.filters
WaveAccess.xop
WaveAccess64.xop

5 items   1 item selected 1.21 KB

The Visual C++ project files are inside the VC folder, to keep them separate from the files for the other development systems. The discussion assumes this arrangement and we recommend that you use it. Note that the compiled XOPs are in the WaveAccess/VC folder.

WaveAccess.vcxproj is the Visual C++ project file and WaveAccess.sln is the Visual C++ “solution” file. To open the project, open the solution file in Visual Studio. You may see other Visual C++-created folders and files. They contain data created by Visual C++, such as compiled object code. Only the .vcxproj, .vcxproj.filters and .sln files are essential for recreating the project.

WaveAccess.cpp contains the project source code while WaveAccess.h contains the project headers.

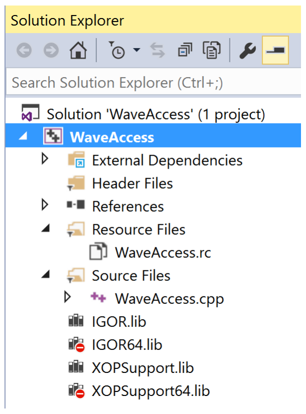
WaveAccess.rc is the main Windows resource file. It #includes resource.h and WaveAccessWinCustom.rc.

WaveAccess.rc contains standard Windows resources such as the version resource and menu and dialog resources, if any. Long ago, Visual C++ included a graphical resource editor which you used to create and edit standard Windows resources. The graphical resource editor created and managed the resource.h file. Then Microsoft removed the graphical resource editor from the free versions of Visual C++. Consequently, if you use a free version, you must edit these files using a text editor.

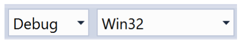
WaveAccessWinCustom.rc contains XOP-specific resources that you edit as text. Igor examines these custom resources to determine what operations, functions and menus the XOP adds, among other things. The use of these resource files is further explained under **XOP Resources** on page 53.

WaveAccess.r contains the Macintosh resources and is not used on Windows.

This screen shot of the Visual C++ Solution Explorer window shows the source files and libraries that are used in the project.



The project is set up to compile either a debug version or a release version of the XOP as a 32-bit or 64-bit XOP. You select which will be built by choosing Build→Configuration Manager or using the configuration popup menus in the Visual C++ toolbar:



Both the debug and release 32-bit configurations create an XOP in the VC folder with the same name (e.g., WaveAccess.xop). During development, you will normally compile using the debug configuration. Once your XOP is in final form, you should build the release configuration which may run significantly faster.

To compile the 64-bit version, choose x64 instead of Win32 from the platform popup menu and then compile the project. This creates a 64-bit version (e.g., WaveAccess64.xop) in the VC folder. 64-bit XOPs are discussed in detail under **64-bit XOPs** on page 171.

Visual C++ Project Settings

If you choose View→Solution Explorer and then right-click the WaveAccess icon and then choose Properties, Visual C++ displays the project settings. Here is a discussion of the significant settings which need to be changed from the default using WaveAccess as an example.

If you change a setting, you should change it for both the debug and release configurations and for the 32-bit and 64-bit platforms unless otherwise noted.

General Properties

Output Directory: .\

This tells Visual C++ to put the compiled XOP in the VC folder.

Target Name: WaveAccess for 32-bits; WaveAccess64 for 64-bits

Target Extension: .xop

Character Set: Use Multi-Byte Character Set

Debugging Properties

Command: Enter the path to your Igor.exe application file for the 32-bit platform, Igor64.exe for the 64 bit platform.

Visual C++ will launch Igor when you ask to debug your XOP.

C/C++ Properties / General Category

Additional Include Directories: Add ..\..\XOPSupport

This allows #include statements to find the XOPSupport header files. The path is relative to the folder containing the .vcxproj project file.

The final setting will contain "..\..\XOPSupport;%(AdditionalIncludeDirectories)". The latter part is automatically added by Visual C++ by default.

C/C++ Properties / Preprocessor

Preprocessor Definitions: Add _CRT_SECURE_NO_WARNINGS

This setting must be added separately for the debug and release configurations for both the 32-bit and 64-bit platforms because other preprocessor definitions are configuration-specific.

C/C++ Properties / Code Generation Category

Runtime Library: Multi-Threaded (/MTd) for the debug configuration; Multi-Threaded (/MT) for the release configuration.

Do not use a DLL version of the runtime library as the DLL is not present on all systems.

An exception to this rule is that, if you have to link with a library compiled with a different version of Visual C++, you may get link errors relating to missing C runtime routines. In this case you have no choice but to use the DLL versions of the C runtime. Then anyone using your XOP will need to have the C runtime DLLs for your Visual C++ version. For further information, search the web for "Visual C++ redistributable".

Struct Member Alignment: Default

See **Structure Alignment** on page 193 for details.

C/C++ Properties / Command Line

Additional Options: Add /utf-8

This setting tells the compiler to compile literal strings as UTF-8. For background information, see **Text Encodings in Visual C++** on page 187.

Linker Properties / General Category

Output File: WaveAccess.xop for 32-bits; WaveAccess64.xop for 64-bits

The normal Visual C++ arrangement is to have the output file created in the Debug or Release folder created by Visual C++ inside the project folder (WaveAccess\VC). However we set up both the Debug and Release configurations to create the output file in the project folder so that a shortcut placed in the Igor extensions folder will always refer to the last compiled version, regardless of configuration.

Linker Properties / Input Category

Additional Dependencies: Add version.lib.

The final setting will contain "version.lib;%(AdditionalDependencies)". The latter part is automatically added by Visual C++ by default.

Linker Properties / System Category

Enable Large Addresses: Yes (/LARGEADDRESSAWARE)

This allows the XOP to address up to 4 GB when running with the 32-bit version of Igor instead of the default 2 GB.

Linker Properties / Advanced Category

Target Machine: MachineX86 for 32-bit XOPs; MachineX64 for 64-bit XOPs.

Resources Properties / General Category

Additional Include Directories: ..\..\XOPSupport

The final setting will contain "..\..\XOPSupport;%(AdditionalIncludeDirectories)". The latter part is automatically added by Visual C++ by default.

This allows #include statements to find the XOPResources.h file. The path is relative to the folder containing the .vcxproj project file.

Debugging a Visual C++ XOP

Here are the steps that you can take to debug a Visual C++ XOP.

1. Open the solution (e.g., WaveAccess.sln) in Visual C++.
2. Use Build→ Configuration Manager or the configuration popup menus to activate the debug configuration of the project.
3. In the Solution Explorer window, right-click the WaveAccess icon, choose Properties, click the Debugging category, and set the Command setting for the debug configuration to the path to your Igor.exe or Igor64.exe file.
4. Build the XOP by choosing Build→Build Solution.
5. On the desktop, make a shortcut for the XOP and activate it as described under **Activating XOPs Using the Igor Extensions Folder** on page 6.
6. Back in Visual C++, open your main source file (e.g., WaveAccess.cpp), and set a breakpoint at the start of the XOPMain function.
7. Press F5. The Visual C++ debugger will launch Igor Pro.
8. If your XOP adds one or more external functions, Igor will launch it at this time, in which case you should break into Visual C++ at the point in the XOPMain function where you set the breakpoint.

9. If your XOP does not add external functions, do something to cause Igor to launch it, such as invoking your external operation from Igor's command line. You should break into Visual C++ at this point.

Igor/XOP Interactions

Overview

The code on page 52 is a simplified sketch of XOP1, a simple XOP that adds a single command line operation to Igor. The underlined items are functions, constants or structures defined in the XOPSupport library and headers. Read the code now but don't worry about the details which we will explain next.

To get a feeling for how Igor and the XOP interact, we will follow a chain of events in chronological order.

1. When Igor is launched, it scans the Igor Extensions folder ("Igor Extensions (x64)" for IGOR64, "Igor Extensions" IGOR32) and any subfolders looking for XOPs identified by their ".xop" file name extension. When Igor finds an XOP, it first looks for its XOPI resource, from which Igor determines various characteristics of the XOP.
2. Next Igor looks for resources that identify what things (external operations, external functions, menu items, menus) the XOP adds. In the example below, the XOPC resource tells Igor that the XOP adds a command line operation named XOP1. This resource is stored in the XOP's resource fork and is defined in the XOP1.r file on Macintosh and in the XOP1WinCustom.rc file on Windows.
3. The user invokes the XOP1 operation via Igor's command line or via a procedure.
4. Igor loads the XOP into memory and calls the XOP's XOPMain function, passing it an IORecHandle. The XOPMain function does all of the XOP's initialization including calling the following XOPSupport routines.

Routine	Description
XOPInit	Stores the IORecHandle in a global variable which is used by all subsequent XOPSupport calls.
SetXOPEntry	Sets a field in the IORecHandle pointing to the XOP's XOPEntry routine. Igor uses this routine for subsequent calls to the XOP except for external operation and external function invocations.
RegisterOperation	Tells Igor the syntax of the XOP1 external operation and the address of the function (ExecuteXOP1) that Igor must call to execute the operation.
SetXOPResult	Sets the result field in the IORecHandle to zero. This tells Igor that the initialization succeeded.

5. Igor parses the command's parameters, stores them in a structure, and calls ExecuteXOP1, passing the structure to it.
6. The ExecuteXOP1 function does the necessary work and returns a result to Igor. The result is zero for success or a non-zero error code.
7. If the result returned to Igor is non-zero, Igor displays an error alert.

```
// From XOP1.r for Macintosh.
resource 'XOPC' (1100) {      // Describes operations the XOP adds to Igor.
   {
      "XOP1",                            // Name of operation.
      XOPOp + utilOp + compilableOp,     // Operation's category.
   }
};

// From XOP1WinCustom.rc for Windows.
1100 XOPC                     // Describes operations the XOP adds to Igor.
BEGIN
   "XOP1\0",                             // Name of operation.
   XOPOp | utilOp | compilableOp,        // Operation's category.
   "\0"                                  // NULL required to terminate resource.
END

// From XOP1.cpp for Macintosh and Windows.

extern "C" int
ExecuteXOP1(XOP1RuntimeParamsPtr  p)
{
   int result;
   result = <XOP-specific code to implement command line operation>;
   return result;
}

static int
RegisterXOP1(void)
{
   char* cmdTemplate;
   cmdTemplate = "XOP1 wave";
   return RegisterOperation(cmdTemplate,  . . ., (void*)ExecuteXOP1, . . .)
}

extern "C" void
XOPEntry(void)
{
   XOPIORecResult result = 0;
   switch (GetXOPMessage()) {
      // Handle message
   }
   SetXOPResult(result);
}

HOST_IMPORT int
XOPMain(IORecHandle ioRecHandle) // The main function
{
   XOPInit(ioRecHandle);
   SetXOPEntry(XOPEntry);

   if (igorVersion < 800) {      // Requires Igor Pro 8.00 or later.
      SetXOPResult(IGOR_OBSOLETE);
      return EXIT_FAILURE;
   }

   RegisterXOP1();
   SetXOPResult(0L);
   return EXIT_SUCCESS;
}
```

When the user invokes an XOP's external operation or external function, in most cases Igor directly calls a function which was registered by the XOP for that operation or function. Chapter 5 and Chapter 6 discuss the details of creating external operations and functions.

Except for calling an external operation or an external function, all communications from Igor to the XOP go through the XOPEntry routine. For example, if the XOP adds a menu item to an Igor menu, when the user chooses the menu item Igor calls XOPEntry, passing the MENUITEM message and parameters in fields of the IORecHandle. The XOPEntry routine then calls **GetXOPMessage** to determine what message Igor is sending and **GetXOPItem** to obtain parameters associated with the message.

The IORecHandle is managed completely by the XOPSupport library routines. Except for passing the IORecHandle to the **XOPInit** function during initialization, you can completely ignore it.

In the example above, the XOPEntry and ExecuteXOP1 functions are declared `extern "C"`. This is required in C++ code because all calls between Igor and the XOP use C calling conventions. If you are coding the XOP in C instead of C++, use `static` in place of `extern "C"`.

XOP Resources

There are three types of resources that you can use in your XOP:

Type of Resource	Defined By	Examples
XOP-specific	WaveMetrics	XOPI, XOPC, XOPF
Platform-specific	Apple, Microsoft	Menus, dialogs
Your own resources	You	Whatever you define

The XOP-specific resources describe your XOP to Igor. This section discusses the form and meaning of these resources. This table lists all of the XOP-specific resources:

Resource	What It Does	Explained In
XOPI 1100	Describes XOP's general properties to Igor.	This chapter
XOPC 1100	Defines operations added by the XOP.	Chapter 5
XOPF 1100	Defines functions added by the XOP.	Chapter 6
STR# 1100	Defines error messages added by the XOP.	Chapter 12
STR# 1101	Miscellaneous XOP strings that Igor needs to know about.	Chapter 8
STR# 1160	Used by XOPs that add target windows.	Chapter 9
XMN1 1100	Defines main menu bar menu added by XOP.	Chapter 8
XMI1 1100	Defines menu items added to Igor menus.	Chapter 8
XSM1 1100	Defines submenus used by XOP.	Chapter 8

The STR# resource is a standard Apple resource format. The other listed resource types are custom XOP resource formats. These resource types are used on both Macintosh and Windows.

All XOPs must have an XOPI resource. Igor will refuse to run your XOP if it lacks this. All of the other resources are required only if the XOP uses the associated features.

Simple XOPs typically have an XOPI resource, an XOPC or XOPF resource, a STR#,1100 resource, and a STR#,1101 resource.

Creating Resources on Macintosh

You create Macintosh resources by editing a .r file as text and then letting Xcode compile the .r file. You should start with a .r file from a WaveMetrics sample XOP.

Xcode includes a resource compiler that compiles any .r files in the project. The resulting resources are stored in the .rsrc file in the XOP's package folder.

The XOPTypes.r XOPSupport file defines the format of the custom WaveMetrics resource types such as XOPI, XOPC and XOPF. XOPTypes.r is #included in your .r file so that the resource compiler can compileXOP resources.

Creating Resources on Windows

On Windows, Visual C++ creates resources by compiling resource (.rc) files. You can create a resource file either by entering text directly into the file or by using the development system's graphical resource editor. However the free editions of Visual C++ do not support graphical resource editing so you must enter text directly into the file using the source code editor.

The graphical resource editor allows you to graphically edit standard Windows resources such as icons, menus and dialogs. The source code editor allows you to edit a resource file as plain text, which is better for editing text-oriented resources such as XOP function declarations, operation declarations and error strings.

To open a resource file for graphical editing, double-click its icon in the Solution Explorer. To open it for text editing, right-click it and choose View Code.

On Windows, the XOP-specific resources are stored in a separate resource file which is edited as a text file. For example, the XOP1 sample XOP has two resource files, an XOP1.rc file that stores standard Windows resources (e.g., version and menu resources) and an XOP1WinCustom.rc file that stores WaveMetrics-defined resources (e.g., XOPI, XOPC and XOPF resources).

Visual C++ allows you to add only one resource file to your project. Consequently, the main resource file (XOP1.rc) contains an include statement which includes the XOP-specific resource file (XOP1WinCustom.rc). You can see this by opening the XOP1.rc file using the source code editor. You will see this line:

```
#include "XOP1WinCustom.rc"
```

The Visual C++ graphical resource editor generates a file named resource.h, which is also included by the main resource file.

The XOPI 1100 Resource

There is one resource that must be present in every XOP. That is the XOPI 1100 resource. This resource tells Igor a few things about your XOP.

Here is the code defining the XOPI resource. It is suitable for all XOPs compiled by XOP Toolkit 8:

```
// Macintosh
#include "XOPStandardHeaders.r"  // Defines XOP-specific types and symbols.
resource XOPI (1100) {  // XOPI - Describes general XOP properties to Igor.
   XOP_VERSION,         // XOP protocol version.
   DEV_SYS_CODE,        // Code for development system used to make XOP.
   XOP_FEATURE_FLAGS,   // Tells Igor about XOP features
   XOPI_RESERVED,       // Reserved - must be zero.
   XOP_TOOLKIT_VERSION, // Version of XOP Toolkit used to create XOP.
};

// Windows
#include "XOPResources.h"     // Defines symbols used below.
1100 XOPI               // XOPI - Describes general XOP properties to Igor.
```

```
BEGIN
   XOP_VERSION,         // XOP protocol version.
   DEV_SYS_CODE,        // Code for development system used to make XOP.
   XOP_FEATURE_FLAGS,   // Tells Igor about XOP features
   XOPI_RESERVED,       // Reserved - must be zero.
   XOP_TOOLKIT_VERSION, // Version of XOP Toolkit used to create XOP.
END
```

If the XOPI 1100 resource is missing then Igor will not run the XOP.

The symbols XOP_VERSION, DEV_SYS_CODE, XOP_FEATURE_FLAGS, and XOP_TOOLKIT_VERSION are defined in XOPResources.h which is included by XOPStandardHeaders.r. The values of these macros are automatically set; you don't need to change them.

The first field is used to make sure that the XOP is compatible with the XOP interface in the version of Igor that is running. This is the version number of Igor's XOP protocol at the time the XOP was compiled, defined by the XOP_VERSION constant in the XOPResources.h file. See **Igor/XOP Compatibility Issues** on page 67 for details.

The next field tells Igor what development system was used to compile the XOP, which previously affected how Igor called the XOP. It is currently not used but must be present.

The next field tells Igor about XOP features. The default value of XOP_FEATURE_FLAGS is appropriate for all XOPs created by XOP Toolkit 8. In it, the XOP_FEATURE_LONG_NAMES bit is set, telling Igor that the XOP supports long object names and long paths. See **Long Names and Paths in XOPs** on page 189 for details.

The next field is reserved for future use.

The final field tells Igor what version of the XOP Toolkit was used to compile the XOP, which in some cases determines aspects of how Igor calls the XOP.

How Igor Calls an XOP

Igor calls your XOP by calling one of four routines:

Event	**How XOP Is Called**
INIT message	Igor sends the INIT message by calling your XOPMain function.
Call external operation	To invoke an external operation added by your XOP, Igor calls a function that you designate directly at initialization time as explained in Chapter 5, **Adding Operations**.
Call external function	To invoke an external function added by your XOP, Igor calls a function that you designate directly at initialization time as explained in Chapter 6, **Adding Functions**.
All other messages	Igor sends all other messages by calling your XOPEntry routine.

Calling external operations and functions is explained in chapters 5 and 6. The rest of this chapter explains messages sent to your XOP by calling your XOPMain function or your XOPEntry routine.

Basic XOP Messages

Here are the basic messages that Igor can send to your XOP's XOPEntry routine, or your XOPMain function in the case of the INIT message. The constants (INIT, IDLE, CMD, etc.) are defined in XOP.h. When Igor calls your XOPEntry routine, you call the **GetXOPMessage** XOPSupport routine to determine what message is being sent. The arguments listed are arguments Igor is passing to you. You access them using the GetXOPItem XOPSupport routine.

NOTE: You must get the message from Igor and get all of the arguments for the message before you do any callbacks to Igor. For details see **Avoiding Common Pitfalls** on page 221.

A typical XOP will ignore most of these messages and respond to just a few of them.

As part of the response to a message from Igor, your XOP can pass a result code back to Igor using the **Set-XOPResult** XOPSupport routine. The "Result" item in the following descriptions refers to this result code. A result code of 0 indicate success while a non-zero result code indicates an error. See **XOP Errors** on page 59 for details on the error codes that you can return to Igor.

INIT

Tells your XOP that it needs to initialize itself.

Arguments:	None.
Result:	Error code from your initialization.

This is the first message received by every XOP when it is loaded. This message is sent by calling your XOPMain function. Subsequent messages are sent by calling your XOPEntry routine.

If your XOP returns a non-zero result via the SetXOPResult XOPSupport routine, Igor will unload your XOP immediately. Therefore you should do any necessary cleanup before returning a non-zero result.

IDLE

Tells your XOP to do its idle processing.

Arguments:	None.
Result:	None.

Your XOP gets this message if it has set the IDLES bit using the SetXOPType XOPSupport routine. You should do this if your XOP has tasks that it needs to do periodically so that you'll get the periodic IDLE message.

See **Handling Recursion** on page 66 for a discussion of recursion issues involving IDLE messages.

MENUITEM

Tells your XOP that its menu item has been selected.

Argument 0:	Menu ID of menu user selected.
Argument 1:	Item number of item user selected.
Result:	Your result code from operation.

Your XOP must determine which of its menu items has been invoked and respond accordingly. It should call SetXOPResult to pass zero or an error code back to Igor.

See Chapter 8, **Adding Menus and Menu Items**, for details on how to respond to this message.

MENUENABLE

Tells your XOP to enable or disable its menu items.

Arguments:	None.
Result:	None.

If your XOP has one or more menu items, it receives this message when the user clicks in the menu bar or presses a command-key equivalent (*Macintosh*) or accelerator (*Windows*). This message gives your XOP a chance to enable, disable or change its menu items as appropriate.

An XOP receives the MENUENABLE message if its window is the front window even if the XOP adds no menu items to Igor. This allows the XOP to enable or disable Igor menu items such as items in the Edit or File menu.

See Chapter 8, **Adding Menus and Menu Items**, for details on how to respond to this message.

CLEANUP

Tells your XOP that it is about to be closed and discarded from memory.

Arguments:	None.
Result:	None.

Your XOP should dispose any memory that it has allocated and do any other necessary cleanup.

Igor6 sends the CLEANUP message before Igor kills all experiment data. Igor7 and later send it after.

OBJINUSE

Allows your XOP to tell Igor that it is using a particular object.

Argument 0:	Object identifier.
Argument 1:	Object type.
Result:	Zero if your XOP is not using the object, one if it is using the object.

Igor passes this message to your XOP when it is about to dispose of an object (e.g., kill a wave) that your XOP may depend upon.

At present, the only use for this is to tell Igor that your XOP is using a particular wave so that Igor will not let the user kill the wave. The object identifier is the wave handle. The object type is WAVE_OBJECT. Object types are defined in IgorXOP.h.

You need to respond to this message if your XOP depends on a particular wave's existence. Otherwise, ignore it.

The OBJINUSE message is sent only from the main Igor thread. A complementary technique is available for preventing the deletion of waves used in an Igor preemptive thread. See **Wave Reference Counting** on page 131 for details.

When a new experiment is loaded or Igor quits, all objects are killed, whether they are in use or not. Therefore, if your XOP expects one or more Igor objects to exist, the XOP must be prepared to stop using the objects when either of these events occurs. Igor calls your XOP with the NEW message when a new experiment is about to be opened and with the CLEANUP message when Igor is about to quit.

See **Preventing the Killing of a Wave** on page 130 for further discussion of the OBJINUSE message.

FUNCADDRS

Asks your XOP for the address of one of its external functions.

Argument 0:	Function index number starting from 0.
Result:	Address of function or NULL.

See Chapter 6, **Adding Functions**, for details.

Messages for XOPs that Save and Load Settings

An elaborate XOP can save settings and/or documents as part of an Igor experiment and load those settings and documents when the user reopens the experiment. To do this, your XOP needs to respond to the messages in this section.

NEW

Tells your XOP that the current experiment is being unloaded, for example, when the user selects New Experiment from the File menu.

Arguments:	None.
Result:	None.

When the user creates a new experiment your XOP should set its settings to their default state.

Igor7 and later send the NEW message when Igor is about to quit. Igor6 does not send the NEW message at that time.

MODIFIED

Asks your XOP if it has been modified since the last NEW, LOAD or SAVE message and needs to save settings or documents.

Arguments:	None.
Result:	0 if your XOP is not modified, 1 if modified.

You need to respond to this message if your XOP saves settings or documents as part of an experiment. Otherwise, ignore it.

CLEAR_MODIFIED

Igor sends this message during its initial startup, and after Igor generates a new experiment (in response to the user choosing New Experiment), and after Igor finishes loading an experiment (in response to the user choosing Open Experiment or Revert Experiment), and after Igor finishes saving an experiment (in response to the user choosing Save Experiment or Save Experiment As). An XOP that saves data in experiment files can use this message to clear its modified flag.

Arguments:	None.
Result:	None.

SAVE

This message is obsolete. Igor Pro will not send it.

LOAD

This message is obsolete. Igor Pro will not send it.

SAVESETTINGS

Allows your XOP to save settings as part of an experiment.

Argument 0:	Experiment type.
Argument 1:	Save type.
Result:	Handle to your XOP’s settings or NULL.

Your XOP can save its settings in the experiment file. If you want to do this, return a handle to the settings data to be saved. Otherwise, ignore the message. See **Saving and Loading XOP Settings** on page 63 for details.

If you return a handle, Igor stores the data in the experiment file and disposes the handle. Don’t access the handle once you pass it to Igor.

The experiment type will one of the following which are defined in IgorXOP.h:

EXP_PACKED
EXP_UNPACKED

The save type will be one of the following which are defined in IgorXOP.h:

SAVE_TYPE_SAVE
SAVE_TYPE_SAVEAS
SAVE_TYPE_SAVEACOPY

SAVE_TYPE_STATIONERY

LOADSETTINGS Allows your XOP to load settings it saved in an experiment.

Argument 0:	Handle to data saved in experiment file or NULL.
Argument 1:	Experiment type.
Argument 2:	Load type.
Result:	None.

If your XOP saved its settings in the experiment being opened you should reload those settings from the handle. If your experiment did not save its settings then the handle will be NULL and you should do nothing. See **Saving and Loading XOP Settings** on page 63 for details.

The handle that Igor passes to you comes from the experiment file and will be automatically disposed when Igor closes the experiment file so don't access it once you finish servicing the LOADSETTINGS message.

The experiment type will one of the following which are defined in IgorXOP.h:

EXP_PACKED
EXP_UNPACKED

The load type will be one of the following which are defined in IgorXOP.h:

LOAD_TYPE_OPEN
LOAD_TYPE_REVERT
LOAD_TYPE_STATIONERY
LOAD_TYPE_MERGE

XOP Errors

The XOP protocol facilitates providing helpful error messages when something goes wrong in your XOP. You return an error code to Igor in response to the INIT, CMD, FUNCTION and MENUITEM messages by calling the SetXOPResult XOPSupport routine. Your direct external operations and direct external functions return error codes through the return statement of those routines.

If you return 0, this signifies success - that is, no error occurred. If you return a non-zero value, Igor displays an error dialog. Igor displays the dialog when your XOP returns, not immediately.

In some cases, you may need to display an error dialog other than in response to these messages. In this case you need create your own error dialog routine or use the IgorError XOPSupport routine. See **Displaying Your Own Error Alert** on page 62 for details on how to do this.

The **GetIgorErrorMessage** XOPSupport routine returns an error message for a specified error code. This is useful if you want to display an error message in your own window.

Error Codes

There are three kinds of errors that you can return to Igor:

Type	Range	Description
Igor error code	-1 to 9999	Error codes used by Igor itself. Defined in IgorErrors.h.

Type	Range	Description
Mac OS error codes	-32768 to -2	Defined in IgorErrors.h (see FIRST_MAC_OS_ERR). Used on both Macintosh and Windows.
XOP error codes	10000 to 10999	Defined by the XOP programmer.

You must not return Windows OS error codes to Igor because these codes conflict with Igor error codes. Instead, you must translate Windows OS Error codes into Igor error codes. This is explained below.

Igor Error Codes

An Igor error code is a code for an error that Igor might generate itself. The file IgorErrors.h contains #defines for each of the Igor error codes. Your XOP can return an Igor error code and Igor will display an appropriate error dialog. For example, if your XOP returns NOMEM, Igor displays an "out of memory" error dialog and if your XOP returns NOWAV, Igor displays an "expected wave name" error dialog.

There is one special Igor error code: -1. It signifies an error for which an error dialog is not necessary. Return -1 if the user aborts an operation or if you reported the cause of the error in some other way. This tells Igor that an error occurred but Igor will not display an error dialog.

XOP Custom Error Codes

XOP custom error codes are defined by an XOP. #defines for these error codes should be created in the XOP’s .h file and there must be a corresponding error message in the XOP’s STR# 1100 resource which is described in Chapter 12. Custom error codes are numbered starting from FIRST_XOP_ERR which is defined in XOP.h. The details of adding custom error messages are discussed under **Adding Custom Errors** on page 62.

Mac OS Error Codes

A Mac OS error code is a code for an error generated by the Macintosh operating system. A Mac OS error code is always negative.

The file IgorErrors.h (search for FIRST_MAC_OS_ERR) provides XOP Toolkit emulation of the most common Mac OS error codes. XOPs can return these error codes on both Macintosh and Windows.

Igor provides meaningful error messages for these error codes. For other Mac OS error codes, Igor displays a generic error message.

Handling Windows OS Error Codes

Windows OS error codes conflict with Igor error codes. For example, the error code 1 (NOMEM) means "out of memory" in Igor. On Windows, it means "The function is invalid" (ERROR_ INVALID_FUNCTION). Igor interprets error codes that you return to it as Igor error codes. If you return a Windows OS error code to Igor, you will get an incorrect error message.

On Windows, Igor provides two functions to deal with this problem. **WindowsErrorToIgorError** translates a Windows error code that you get from the Windows GetLastError function into an error code that Igor understands. **WMGetLastError** is a WaveMetrics substitute for the Windows GetLastError function that also returns error codes that Igor understands.

Here is an example illustrates how you might use WindowErrorToIgorError.

```
int
Test(void)                // Returns 0 if OK or a non-zero error code.
{
   int err;

   if (SetCurrentDirectory("C:\\Test") == 0) {
      err = GetLastError();
      // You can add code to examine err here, if necessary.
      err = WindowsErrorToIgorError(err);
      return err;       // Return code to Igor.
   }
   return 0;
}
```

This is the recommended technique if your own code needs to examine the specific error code returned by GetLastError. Usually, the precise error code that GetLastError returns does not affect the flow of your code. In such cases, we can rewrite the function using WMGetLastError, which itself calls GetLastError and WindowsErrorToIgorError.

```
int
Test(void)              // Returns 0 if OK or a non-zero error code.
{
   int err;

   if (SetCurrentDirectory("C:\\Test") == 0) {
      err = WMGetLastError();
      return err;       // Return code to Igor.
   }
   return 0;
}
```

In addition to translating the error code, WMGetLastError is different from GetLastError in two regards. First, it always returns a non-zero result. Second, it calls SetLastError(0) after it calls GetLastError. The following example illustrates why WMGetLastError does these things.

```
/* GetAResource(hModule, resID, resType)

   Returns 0 if OK or non-zero error code.
*/
int
GetAResource(HMODULE hModule, int resID, const char* resType)
{
   HRSRC hResourceInfo;

   hResourceInfo=FindResource(hModule,MAKEINTRESOURCE(resID),resType);
   if (hResourceInfo == NULL) {  // hResourceInfo is NULL
      err = GetLastError();      // but GetLastError returns 0.
      return err;                // So we return 0 but hResourceInfo is NULL.
   }
   .
   .
   .
}
```

The Windows documentation for FindResource says "If the function fails, the return value is NULL. To get extended error information, call GetLastError.

However, empirical evidence indicates that, if the resource is not found, FindResource returns NULL, but *does not* set the last error. Therefore, GetLastError returns a stale error code - whatever was set by some previous Windows API call. If this happens to be zero, then the function above will return zero and the calling routine will think that it succeeded, with possibly disastrous results.

If you use WMGetLastError instead of GetLastError, you will always get a non-zero result, avoiding the disaster. WMGetLastError calls GetLastError and, if GetLastError returns 0, WMGetLastError returns WM_UNKNOWN_ERROR. Furthermore, since WMGetLastError calls SetLastError(0) after calling GetLastError, you can be certain that we will not get a stale error code the next time we call it.

You should call GetLastError or WMGetLastError only when you have received another indication of failure from a Windows API call. For example, FindResource signals a failure by returning NULL. You should not call GetLastError or WMGetLastError if FindResource returns non-NULL. This is because Windows API routines do not set the last error code if they succeed. They set it only if they fail, and sometimes not even then.

Adding Custom Errors

Each time your XOPEntry routine receives the INIT, CMD, FUNCTION or MENUITEM message, you must return an error code to Igor using the SetXOPResult XOPSupport routine. Also, your direct external operations and direct external functions must return an error code as their function result.

If you return 0, this signifies success - that is, no error occurred. If the error code is non-zero, Igor will display an error dialog when your XOP returns.

Custom XOP error codes are codes that you define for your XOP, typically in a .h file of your own. For each code, you define a corresponding error message. You store the error messages in your STR# 1100 resource in the resource fork of your XOP.

The custom error codes for your XOP must start from FIRST_XOP_ERR+1. FIRST_XOP_ERR is defined in the XOP.h file. As an illustration, here are the custom error codes for the XFUNC3 sample XOP as defined in XFUNC3.h.

```
#define OLD_IGOR 1 + FIRST_XOP_ERR
#define UNKNOWN_XFUNC 2 + FIRST_XOP_ERR
#define NO_INPUT_STRING 3 + FIRST_XOP_ERR
```

Here is XFUNC3's STR# 1100 resource, which defines the error messages corresponding to these error codes.

```
// Macintosh, in XFUNC3.r.
resource 'STR#' (1100) {   // Custom error messages
   {
      "XFUNC3 requires Igor Pro 8.00 or later.",
      "XFUNC3 XOP was called to execute an unknown function.",
      "Input string is non-existent.",
   }
};

// Windows, in XFUNC3WinCustom.rc.
1100 STR#
BEGIN
   "XFUNC3 requires Igor Pro 8.00 or later.\0",
   "XFUNC3 XOP was called to execute an unknown function.\0",
   "Input string is non-existent.\0",
   "\0"                     // NULL required to terminate the resource.
END
```

Displaying Your Own Error Alert

Igor displays an error alert if you return a non-zero error code in response to the INIT, CMD, FUNCTION and MENUITEM messages or as the function result of a direct external operation or direct external function. You can call the **IgorError** XOPSupport routine to display an alert at other times. IgorError accepts an Igor, Mac OS, or XOP-defined error code and displays a dialog with the corresponding message.

You may want to display an error message in your own dialog or window. In this case, call **GetIgorErrorMessage**. GetIgorErrorMessage accepts an Igor, Mac OS, or XOP-defined error code and returns a string containing the corresponding message.

To display your own alert using a string that is not associated with an error code, you can use the **XOPOKAlert**, **XOPOKCancelAlert**, **XOPYesNoAlert**, and **XOPYesNoCancelAlert** XOPSupport routines.

Eliminate Empty XOP Error Strings

To support external operations and functions running in threads, at launch time, Igor copies all XOP error strings from the XOP's STR# 1100 resource into Igor memory.

If you have an empty error string in your STR# 1100 resource, this will cause Igor to ignore any error strings after the empty one. If you have an unused error message that is currently set to "" in your STR# 1100 resource, change it to something like "-unused-".

Also make sure that your XOP error codes, defined in your main .h file, are contiguous starting from (FIRST_XOP_ERR + 1).

XOPs and Preferences

If you are writing an XOP that has a user interface, you may want to save certain bits of information so that the user does not need to re-enter them each time he or she uses the XOP. For example, the GBLoadWaveX XOP saves the state of many of its dialog items and restores them the next time the user invokes the dialog.

The **SaveXOPPrefsHandle** XOPSupport routine saves your XOP's data in Igor preferences. You can later retrieve this data by calling the **GetXOPPrefsHandle** XOPSupport routine. Your data is stored in a file in the XOPs folder of the Igor preferences folder. The file is maintained by Igor and you should access it only via the SaveXOPPrefsHandle and GetXOPPrefsHandle functions.

Each time you call either of these routines, the file is opened and closed. Therefore it is best to call each of them only once. One way to do this is to call GetXOPPrefsHandle when your XOP starts and SaveXOPPrefsHandle when you receive the CLEANUP message.

The **GetPrefsState** callback provides a way for you to know if preferences are on or off. This allows an XOP to behave like Igor in regard to when user preferences are used versus when factory default preferences are used, as described in the Igor Pro manual.

The data that you store will often be in the form of a structure. As time goes by, you may want to add fields to the structure. In that case, you have the problem of what happens if an old version of your XOP receives the new structure. The easiest way to deal with this is to define an ample amount of reserved space in the very first incarnation of your structure. Set all of the reserved space to zero. In future versions you can use some of the reserved space for new fields with the value zero representing the default value. Old versions of your XOP will ignore the new fields. Also, it is a good idea to make the first field of your structure a version field.

XOPs and Experiments

If you develop an elaborate XOP, you might want it to store settings or documents as part of an Igor experiment. Igor provides help in doing this.

When the user creates a new experiment or opens an existing experiment, Igor sends you a NEW message. You should reset your XOP settings to their default state. When the user opens an experiment, Igor sends the LOADSETTINGS message. When the user saves an experiment, Igor sends the SAVESETTINGS message.

Saving and Loading XOP Settings

If your XOP has settings that it wants to save in each experiment then you need to respond to the SAVESETTINGS and LOADSETTINGS messages. See the XOPSaveSettings and XOPLoadSettings routines in VDT2:VDT.cpp for an example of responding to these messages.

When the user saves an experiment, Igor sends your XOP the SAVESETTINGS message. If you want to save settings in the experiment, you need to create a handle containing the settings. Return this handle to Igor using the SetXOPResult routine. Once you've passed this handle back to Igor, it belongs to Igor, so don't access, modify, or delete it.

Your data is stored in a record of a packed experiment or in the miscellaneous file inside the home folder of an unpacked experiment. You should not attempt to access the data directly since the method by which it is stored could be changed in future versions of Igor.

When the user opens an experiment, after sending the NEW message, Igor sends the LOADSETTINGS message. The primary argument to this message, which you access using the GetXOPItem call, is the handle to the settings that you saved in response to the SAVESETTINGS message or NULL if you saved no settings in the experiment being opened. If the handle is NULL, set your XOP to its default state. If it is not NULL, use this handle to restore your XOP to its previous state. The handle belongs to Igor and Igor will dispose it when you return. If you need to, make a copy of the handle.

Igor sends the LOADSETTINGS message during the experiment recreation process before any of the experiment's objects, such as waves, variables and data folders, have been created. If your settings contain a reference to an Igor object, you will not be able to access the object until the experiment recreation process is complete. For example, if your XOP receives IDLE messages, you can access the object on the first IDLE message after the LOADSETTINGS message. You can also use the CLEAR_MODIFIED message for this purpose.

If your XOP is to run cross-platform, you must take special measures so that you can use settings stored on Macintosh when running on Windows and vice-versa. Unless you take precautions, structures that you declare on one platform may not have the same layout as structures that you declare on the other platform, because of different structure alignment methods. There may also be differences in structure alignment between 32-bit and 64-bit code on the same platform.

To make sure that your structures have the same layout on all platforms and in 32 bits versus 64 bits, you need to tell the compiler how you want structures laid out. The sample XOPs on both Macintosh and Windows use two-byte alignment for all structures that are stored on disk or exchanged with Igor, thus satisfying this condition. This is done using the pack pragma. For details on this, see **Structure Alignment** on page 193.

The data that you store will often be in the form of a structure. As time goes by, you may want to add fields to the structure. In that case, you have the problem of what happens if an old version of your XOP receives the new structure. The easiest way to deal with this is to define an ample amount of reserved space in very first incarnation of your structure. Set all of the reserved space to zero. In future versions you can use some of the reserved space for new fields with the value zero representing the default value. Old versions of your XOP will ignore the new fields. Also, it is a good idea to make the first field of your structure a version field.

The IORecHandle

The IORecHandle is a handle to an IORec data structure which contains all of the information that Igor and the XOP need to share. Each XOP has a global variable of type IORecHandle named XOPRecHandle which is defined in XOPSupport.c. The value of XOPRecHandle is set when your XOP's XOPMain function calls XOPInit.

You should never deal with the IORecHandle directly since the routines in XOPSupport.c do this for you.

Resident and Transient XOPs

The XOPType field of the IORecHandle indicates to Igor the capabilities or mode of the XOP. You can set this field using the **SetXOPType** XOPSupport routine but this is not necessary for most XOPs. The value of XOPType will be some combination of the following bit-mask constants which are defined in XOP.h.

Constant	What It Means
RESIDENT	XOP wants to remain in memory indefinitely.
TRANSIENT	XOP wants to be closed and discarded.

Constant	What It Means
IDLES	XOP wants to receive periodic IDLE messages.
ADDS_TARGET_WINDOWS	XOP adds a target window type to Igor.

The XOPType field is inititialized by Igor to RESIDENT. This means that the XOP will stay in memory indefinitely. All XOPs that add operations or functions to Igor must be resident. XOPs that perform ongoing services in the background, such as data acquisition XOPs, must also be resident. XOPs that are called very frequently should be resident to avoid the need to repeatedly load and unload them.

In the distant past, when memory was a very scarce commodity, it was advantageous to make an XOP transient if possible. Now, because of the greater availability of memory and because XOPs that add operations or functions are not allowed to be transient, it is no longer recommended.

For the rare case where it is wise to make an XOP transient, here is how you do it. Once your operation has done its work, call SetXOPType(TRANSIENT). Shortly thereafter Igor will call your XOP with the CLEANUP message and will then purge your XOP from memory.

Receiving IDLE Messages For Background Processing

If you want your XOP to receive periodic IDLE messages you need to call

```
SetXOPType(RESIDENT | IDLES)
```

Data acquisition XOPs and other XOPs that provide ongoing background services should make this call.

See **Handling Recursion** on page 66 for a discussion of recursion issues involving IDLE messages.

Messages, Arguments and Results

The XOPEntry field in the IORec structure contains the address of the routine that Igor calls to pass a message to your XOP. The XOPMain function in your XOP must set this field so that it points to your XOPEntry routine by calling the **SetXOPEntry** XOPSupport routine. All subsequent calls from Igor, except for direct operation and direct function calls, go through your XOPEntry routine.

Igor calls your XOPEntry routine, passing no direct parameters. Instead, Igor stores a message code and any arguments that the message requires in the your XOP's IORecHandle. You call the **GetXOPMessage** XOPSupport routine to determine the message that Igor is sending you. Then, if the message has arguments, you call the **GetXOPItem** XOPSupport routine to get them. GetXOPMessage and GetXOPItem use the global XOPRecHandle that was set when you called XOPInit from your XOPMain function. This scheme was devised in the previous millenium to circumvent the problem of different compilers using different conventions for passing parameter.

Sometimes your response to a message from Igor involves making a call back to Igor to ask it for data or a service. For example, the **FetchWave** callback asks Igor for a handle to a wave with a particular name and the **XOPNotice** callback asks Igor to display some text in the history area. When you make a callback, the XOPSupport routines that implement the callback use the same fields in the IORecHandle that Igor used when it passed the original message to you. For this reason, it is imperative that you get the message and any arguments that Igor is sending to you before doing any callbacks.

NOTE: When Igor passes a message to you, you *must* get the message, using GetXOPMessage, and get all of the arguments, using GetXOPItem, *before* doing any callbacks. The reason for this is that the act of doing the callback overwrites the message and arguments that Igor is passing to you.

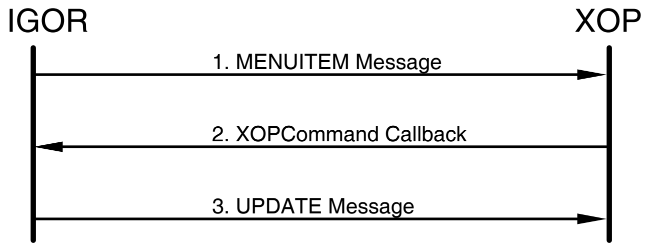
Some messages from Igor require that you return a result. Depending on the particular message, the result may be an error code, a pointer or a handle. You return the result by calling **SetXOPResult**. This XOPSupport routine stores the result in the result field of the IORecHandle.

When you do a callback to Igor, the XOPSupport routines may also use the result field to pass a result from Igor back to your XOP. For this reason, when you are returning a result to Igor, you must call SetXOPResult after doing any callbacks to Igor.

Handling Recursion

This section describes some problems that can occur due to recursion and how to handle them. Simple XOPs will never encounter these problems. XOPs with windows or other elaborate XOPs are more likely to encounter them.

There are some circumstances in which Igor will send a message to your XOP while it is servicing a callback from your XOP. This is recursion and is illustrated in this diagram:



In this example, Igor sends the MENUITEM message to your XOP telling it that the user has invoked one of its menu items. As part of your XOP's response, it does an **XOPCommand** callback to get Igor to do something. As a side effect, the XOPCommand callback causes Igor to update any windows that need updating. If your XOP has a window and it needs updating, Igor will send your XOP the kXOPWindowMessageUpdate message while it is still working on the MENUITEM message. You receive a message at a possibly unexpected time, while you are in the middle of doing something else.

This problem can happen when you call the **XOPCommand**, **XOPSilentCommand**, **SpinProcess** and **DoUpdate** XOPSupport routines and similar routines.

Although this example involves the MENUITEM and kXOPWindowMessageUpdate, the problem is more general. Any time you do a callback to Igor, there is a chance that this will trigger Igor to send another message to you.

For example, if your XOP does IDLE processing, it is possible to receive a second IDLE message from Igor while you are processing the first. One way for this to happen is if, as part of your IDLE processing, you use **XOPCommand** to call a user-defined function that calls Igor's DoXOPIdle operation. DoXOPIdle sends IDLE messages to any XOP that has requested to receive them. There may be other circumstances that lead to Igor sending you an IDLE message while you are processing an earlier IDLE message.

Recursion such as this can cause problems unless you write your XOP to handle it. The problems occur if, in servicing the kXOPWindowMessageUpdate message from Igor, your XOP clobbers information that it needs to finish servicing the MENUITEM message or if your XOP is in a delicate state when it receives the XOP message. Fortunately, it is possible to avoid this.

There are two things that you must do to handle recursion:

1. When Igor calls you with a message, get the message and all of its arguments before doing any callbacks to Igor.
2. Don't use global variables to store things that will change from message to message, including the message and its arguments.

It turns out that most XOPs meet these requirements without any conscious effort on your part.

The reason for the first requirement is that Igor stores its message and arguments in your XOP's IORecHandle. In the example above, when Igor sends the UPDATE message, it clobbers the message and arguments for the MENUITEM message. This is no problem if, as shown in the sample XOPs, you use **GetXOPMessage** and **GetXOPItem** before doing any callbacks to Igor and if you store their results in local variables.

The second requirement is easily met if you just avoid using global variables as much as possible. This is good programming practice anyhow for reasons of modularity and insulation of routines from other routines.

If you use XOPCommand or XOPSilentCommand as part of your initialization, you must be aware that you may receive the kXOPWindowMessageUpdate message before your initialization is complete. It is also possible to receive the kXOPWindowMessageUpdate message at other times when your XOP is in the process of changing its state and can not service the update normally.

The solution for this is to use a flag to defer the true update until your XOP is ready to handle it. You can do this as follows:

1. Set a flag when you enter your XOPEntry routine.
2. If your XOPEntry routine is called again, while the flag is set, short-circuit the message from Igor (details below) and return.
3. Clear the flag when doing a normal exit from your XOPEntry routine.

Similarly, to prevent recursion involving IDLE messages, you would set a global when you receive an IDLE message and clear it when you finish IDLE processing. If you receive another IDLE message while the global is set, you ignore the subsequent IDLE message.

Data Sharing

Igor and your XOP need to share data. For example, your XOP may need to access and manipulate Igor waves, data folders, numeric variables, and string variables. Your external function or external operation may receive numeric and string parameters from Igor and return numeric and string results to it. When you make a callback to Igor, you may pass numeric and string parameters to Igor and receive numeric and string results from it.

When dealing with Igor objects, such as waves, data folders and variables, you must always use XOPSupport routines specific to the particular type of object. These routines are listed under **Routines for Accessing Waves** on page 240, **Routines for Accessing Data Folders** on page 285, and **Routines for Accessing Variables** on page 276.

Simple numeric parameters and results are represented using standard C data types such as int and double.

String parameters and results are represented using Handles. The Handle data type has its roots in the original Macintosh operating system and is still used in XOP programming for backward compatibility. Handles and the routines used to manage them are described under **WM Memory XOPSupport Routines** on page 179.

Igor/XOP Compatibility Issues

XOP Toolkit 8 creates XOPs that require Igor Pro 8.00 or later. If your XOP must run with Igor Pro 6 or 7, or if you are updating an old XOP, you should use XOP Toolkit 7. See **Choosing Which XOP Toolkit to Use** on page 5 for details.

As Igor evolves, WaveMetrics makes every attempt to maintain backward compatibility so that your XOP will continue to work with new versions of Igor. However, you still need to make sure that your XOP is compatible with the version of Igor that is running.

There are two situations that need to be handled:

- The running Igor is too old to work with your XOP.
- Your XOP is too old to work with the running Igor.

To avoid compatibility problems you must do two things:

- Check the version of Igor that is running.
- Set the fields of your XOPI resource correctly.

Checking Igor's Version

It is very easy to make sure that the running Igor is not too old. The XOPInit routine in XOPSupport.c, which your XOP calls from its XOPMain function, sets a global variable, igorVersion, to the version number of the currently running Igor. For version 8.00, igorVersion will be 800.

All XOPs compiled by XOP Toolkit 8 require Igor Pro 8.00 or later. Consequently the XOPMain function in each XOP must contain code like this:

```
if (igorVersion < 800) {       // Requires Igor Pro 8.00 or later.
   SetXOPResult(IGOR_OBSOLETE);
   return EXIT_FAILURE;
}
```

This test must be placed after your call to **XOPInit** and **SetXOPEntry**.

If your XOP uses features added to Igor in version 8.03, you must restrict your XOP to running with Igor Pro 8.03 or later. Put the following in your XOP's XOPMain function:

```
if (igorVersion < 803) {       // Requires Igor Pro 8.03 or later.
   SetXOPResult(IGOR_OBSOLETE);
   return EXIT_FAILURE;
}
```

IGOR_OBSOLETE is an Igor error code, defined in IgorErrors.h. Your XOP's help file should specify what version of Igor your XOP requires.

XOP Protocol Version

The first field of an XOP's XOPI resource stores the "XOP protocol version" and is set to the value XOP_VERSION. When Igor examines XOPs at launch time, it checks this field. If the value in the field is too low or too high, Igor concludes that the XOP is not compatible and does not load the XOP. This provides a way for Igor to make sure that your XOP is sufficiently compatible that it is OK to call its XOPMain function where the XOP can do further version checking.

Igor 1.24 through 1.28 worked with XOPs whose XOP protocol version was 2 or 3.

Igor Pro 2 through Igor Pro 8 work with XOPs whose XOP protocol version is 2, 3 or 4. The current value of XOP_VERSION is 4.

Chapter 5

Adding Operations

Overview

An external operation, like a built-in Igor operation, is a routine that performs an action but has no explicit return value. An operation has the following syntax:

```
<Operation Name> [optional flags] <parameter list>
```

The optional flags generally take one of the following forms:

Form	Description
/F	A flag by itself. Turns an operation feature on.
/F=f	A flag with a parameter.
/F=(f1, f2, . . .)	A flag with a set of numeric parameters.
/F=[f1, f2, . . .]	A flag with a set of numeric indices.
/F={f1, f2, . . .}	A flag with a list of parameters of possibly different types.

Flags can consist of one to four letters (/A, /AB, /ABC or /ABCD).

<parameter list> consists of one or more parameters or keywords. Here are some common forms:

Form	Examples
Numeric expression	3
	sin(K0/3)
	3 + sin(K0/3)
String expression	"Hello"
	date()
	"Today is" + date()
Wave list	wave0, root:wave1, :wave2
Keyword=Value	baud=9600
	extension=".dat"
	dayOfWeek=Monday
	size={3.4,5.2}

A parameter must be separated from the next with a comma.

When you add an operation to Igor, you first need to decide the name of the operation and what flags and parameters it will have. If possible, choose a syntax similar to an existing Igor operation.

The main steps in creating an external operation are:

- Creating the XOPC resource which tells Igor what operations your XOP adds
- Creating an operation template which tells Igor the syntax of your operation
- Writing an ExecuteOperation function which implements the operation
- Writing the code that registers the operation with Igor when your XOP is loaded

Direct Method Versus CMD Message Method

Igor Pro 5 added a feature called “Operation Handler” which greatly simplified the process of creating an external operation. In addition, Operation Handler made it possible to call external operations directly from Igor user-defined functions. Prior to Igor Pro 5, to call an external operation from a user-defined function you had to use a kludge involving Igor’s Execute operation.

Using Operation Handler, you specify an ExecuteOperation function that Igor calls directly. This is called the direct method. Prior to Operation Handler, you added an external operation to Igor by responding to the CMD message. This is called the CMD message method.

The CMD message method is still supported by Igor for the benefit of very old XOPs but is not otherwise used and is not documented in this version of the XOP Toolkit manual.

The Sequence of Events

When Igor starts up, it searches the “Igor Extensions” or “Igor Extensions (64-bit)” folder and subfolders, looking for XOP files. When it finds an XOP file, Igor looks for an XOPC 1100 resource in the file. This resource, if it exists, specifies the names of the operations that the XOP adds to Igor.

When the user invokes one of these operations from Igor’s command line or from a procedure, if the XOP was not already loaded, Igor loads the XOP into memory and calls its XOPMain function. The XOP’s XOPMain function calls **RegisterOperation**, an XOPSupport routine through which the XOP tells Igor the syntax of the operation and the address of the XOP function, called the “ExecuteOperation function”, which Igor should call to implement it.

Next, Igor parses the operation parameters and uses them to fill a structure called the “runtime parameter structure”. It then calls the XOP’s ExecuteOperation function, passing the structure to it.

The XOP carries out the operation and returns a result code to Igor. If the result code is non-zero, Igor displays an error dialog with an appropriate error message.

The sequence of events is similar when an external operation is called from a user-defined function except that Igor loads the XOP when the function is compiled in order to determine the operation’s syntax.

The XOPC 1100 Resource

As an illustration, here is the XOPC resource for the SimpleLoadWave sample XOP.

```
// Macintosh, in the SimpleLoadWave.r file.
resource 'XOPC' (1100) {                // Operations added by XOP.
   {
      "SimpleLoadWave",                 // Name of operation.
      XOPOp + utilOp + compilableOp,    // Operation category specifier.
   }
};

// Windows, in the SimpleLoadWaveWinCustom.rc file.
1100 XOPC                               // Operations added by XOP.
BEGIN
```

```
   "SimpleLoadWave\0",                // Name of operation.
   XOPOp | utilOp | compilableOp,     // Operation category specifier.

   "\0"     // NOTE: NULL required to terminate the resource.
END
```

An XOP can add multiple operations to Igor. In this case, there will be additional name/category pairs in the XOPC resource.

The compilableOp flag tells Igor that this is an Operation Handler-compatible external operation. If this flag is missing, Igor will deal with the external operation using the old CMD message method documented in the XOP Toolkit 3.1 manual. Since the CMD message method is obsolete, all new operations use Operation Handler and therefore the compilableOp flag must be present in the operation category specifier for each operation.

Operation Categories

The operation category specifier is some combination of the symbols shown in the following table. The operation category controls when the operation will appear in Igor's Help Browser Command Help list. For example, if the category includes the XOPOp and dataOp bits, it will appear in the list when All, External or Wave Analysis are selected in the Operations popup menu.

Symbol	Bit Value	Operation Help Dialog Category
displayOp	1	Other Windows
waveOp	2	About Waves
dataOp	4	Wave Analysis
cursorOp	8	Controls and Cursors
utilOp	16	Programming & Utilities
XOPOp	32	External
compilableOp	64	Operation Handler-compatible
graphOp	128	Graphs
tableOp	256	Tables
layoutOp	512	Layouts
allWinOp	1024	All Windows
drawOp	2048	Drawing
ioOp	4096	I/O
printOp	8192	Printing
statsOp	16384	Statistics
threadSafeOp	32768	Thread-safe operation

The compilableOp bit does not affect the Help Browser. It tells Igor that the external operation is implemented using Operation Handler and therefore a call to it can be compiled in a user-defined function.

For most XOPs the category will include the XOPOp and compilableOp bits plus at least one other bit, depending on the functionality of the operation. If in doubt, use utilOp.

If the operation is thread-safe, the XOPC entry for it must include the threadSafeOp flag.

Choose a Distinctive Operation Name

NOTE: The names of an XOP's operations must not conflict with the present or future names of Igor's built-in operations or functions or with the present or future names of any other XOP's operations or functions. *Don't use a vague or general name.* If you choose a name that clearly describes the operation's action, chances are that it will not conflict.

The name that you choose for your operation becomes unavailable for use as a wave name, window name or global variable name. For example, if you name your operation Test then you can not use the name Test for any Igor object. If you have existing experiments that use Test, they will be in conflict with your XOP. Therefore, *pick a name that is unlikely to be useful for any other purpose*. This is especially important if you plan to share your XOP with other Igor users since they are probably not prepared to deal with errors when they open existing experiments.

Operation Handler

Operation Handler is a part of Igor that makes it easy to create an external operation that can be executed from the command line, from a macro or from a user-defined function.

Command line and macro operations are interpreted while user-defined function operations are compiled and then later executed. Operation Handler simplifies implementation of an operation in all of these modes.

Here is an outline of what you need to do to use Operation Handler:

1. Define a command template - a string that describes the syntax and parameters of your operation.
2. Define a runtime parameter structure which contains fields for your operation's parameters arranged in the prescribed order.
3. Write a routine that registers your operation with Igor. This is called your RegisterOperation function.
4. Write a routine that executes your operation, given a pointer to your runtime parameter structure. This is called your ExecuteOperation function.
5. Set the compilableOp bit in the XOPC resource for the operation.
6. If your operation is thread-safe, set the threadSafeOp bit in the XOPC resource for the operation.
7. When your XOP is initialized, call your RegisterOperation function to register your operation.

The good news is that Operation Handler can do steps 2 and 3 for you and can get you started on step 4. This is described in detail under **Creating Starter Code** in the next section.

When your operation is invoked from the command line, from a macro or from a user-defined function, Igor will process any supplied parameters and then call your ExecuteOperation function, passing the runtime parameter structure to you. You will use the parameters to perform the operation.

Operation Handler handles all of the details of compiling your operation in a user-defined function and of parsing parameters when your operation is invoked from the command line or from a macro.

Before we get into the details, we will take a short side trip to see how Operation Handler generates starter code for you.

Creating Starter Code

Operation Handler can automatically generate starter code for you, including a complete definition of your runtime parameter structure, a mostly complete definition of your RegisterOperation function, and a skeleton for your ExecuteOperation function. To get your starter code, you execute a ParseOperationTemplate command from within Igor. ParseOperationTemplate takes your command template, generates the starter code and stores it in the clipboard. Anything previously in the clipboard is overwritten. You can then paste the starter code into your source file.

The best way to use this feature is to create an experiment to store the template for your external operation and create a function within the experiment to create the starter code. For an example, see the experiment "SimpleLoadWave Template.pxp". Your template experiment is created when you create a new XOP project, as explained under **Creating a New Project** on page 24. Alternatively, you can create your template experiment by duplicating a template experiment from another sample XOP.

"SimpleLoadWave Template.pxp" contains the following code:

```
Menu "Macros"
   "CopySimpleLoadWaveCode"
End

Function CopySimpleLoadWaveCode()   // Copies starter code to the clipboard.
   String cmdTemplate = "SimpleLoadWave"
   cmdTemplate += " " + "/A[=name:ABaseName]"
   cmdTemplate += " " + "/D"
   cmdTemplate += " " + "/I"
   cmdTemplate += " " + "/N[=name:NBaseName]"
   cmdTemplate += " " + "/O"
   cmdTemplate += " " + "/P=name:pathName"
   cmdTemplate += " " + "/Q"
   cmdTemplate += " " + "/W"
   cmdTemplate += " " + "[string:fileParamStr]"

   ParseOperationTemplate/T/S=1/C=6 cmdTemplate
End
```

CopySimpleLoadWaveCode copies the starter code to the clipboard. After executing it, or your version of it, you can paste from the clipboard into your source file. The generated code includes the following:

- A comment showing the operation template
- A complete runtime parameter structure
- A skeleton ExecuteOperation function that you need to fill out
- A mostly complete RegisterOperation function which you need to call from your XOPMain function

Before reading further, you may want to open the "SimpleLoadWave Template.pxp" experiment in Igor and execute the CopySimpleLoadWaveCode function. Then paste the generated code into a text file and take a look at it. Don't worry about the details at this point. They are explained in the following sections.

Operation Parameters

Parameters come in two main kinds: flags and main parameters. Main parameters come in two types: simple main parameters and keyword=value main parameters.

```
   SampleOp /F=3 /K={A,3.2}      wave0, wave1
                  |                  |      |
                flags          simple main parameters

   SampleOp /F=3 /K={A,3.2}      waves={wave0,wave1}
                  |                  |
                flags          keyword=value main parameter
```

Flags and keywords can specify a single value (/A=1) or a set of values (/A={1,2,3}). A flag and its values, a keyword and its values, or a simple parameter are each called a "parameter group". Each individual value associated with a flag, keyword or simple parameter is called a "parameter".

Igor Pro 6.30 and later support "qualified" keywords. For example:

```
ModifyGraph mode = 3          // Unqualified: Set all traces to markers mode
ModifyGraph mode(wave0) = 3   // Qualified: Set wave0 only to markers mode
```

Here wave0 is the "qualifier". It narrows the scope of the mode keyword. Qualified keywords are discussed in detail under **Qualified Keywords** on page 80.

Your command template can specify any number of flag groups. As for main parameters, it can specify any number of keyword groups or simple groups, but you can not mix keyword and simple groups as main parameters in the same operation.

When the user invokes the operation, flags and keywords may appear in any order. Simple parameters, if they appear at all, must appear in the order specified in the command template.

Parameters can be required or optional. Optional parameters are described under **Optional Parameters** on page 75. Required parameters must be supplied when the operation is compiled or interpreted. If required parameters are missing, Operation Handler generates the appropriate error message.

The Command Template

You must provide a command template when you call RegisterOperation. A command template is a plain text string which describes the operation's syntax. The format of the command template is:

```
<OperationName> <flag descriptions> <main parameter descriptions>
```

For example:

```
SampleOp /O /P=name:pName /Y={number:n1,number:n2} key1={number:n3,string:s1}
```

This says that the operation name is SampleOp, and that it accepts three flag groups and one keyword group. In this example, the parameter groups are:

```
   /O                                // A flag group with no parameters
   /P=name:pName                     // A flag group with one parameter
   /Y={number:n1,number:n2}          // A flag group with two parameters
   keyword1={number:n3,string:s1}    // A keyword group with two parameters
```

The /P flag takes one parameter of type name. The parameter's mnemonic name is pName. The mnemonic name is used as a field name in the runtime parameter structure that is passed to your ExecuteOperation when your operation is invoked.

Similarly, the /Y flag takes two parameters of type number with mnemonic names n1 and n2. The keyword1 keyword takes two parameters, a number whose mnemonic name is n3 and a string whose mnemonic name is s1. In real life you would choose more meaningful mnemonic names.

The name of the operation must appear in the template without any leading spaces. A space is required before the start of the main parameters. Otherwise spaces are optional and can be added anywhere.

Flag and keyword parameter groups can use parentheses, brackets or braces to enclose a list of parameters. Usually braces are used. The leading parenthesis, bracket or brace is called the "prefix" character and the trailing parenthesis, bracket or brace is called the "suffix" character.

Parameters within a group are separated by commas.

In flag parameters, there is no separator between one group and the next:

```
SampleOp /A=number:n1 /B=string:s1
```

In main parameters, one group is separated from the next by a comma:

```
SampleOp number:n1, string:s1
SampleOp key1=number:n1, key2=string:s1
```

There are two exceptions to this. The keywords 'as' and 'vs' can be used in place of comma between one simple main parameter and the next. These are special cases that supports syntax like this:

```
Save wave:w1 as string:s1
```

```
Display wave:yWave vs wave:xWave
```

These special cases do not work if the first parameter is numeric.

The 'as' or 'vs' keyword must appear both in the command template and in the actual command.

The recognized parameter type keywords are:

```
    number
    string
    name
    doubleName
    wave
    waveRange
    varName
    dataFolderRef
    dataFolderAndName
    structure
```

Most operations will use number, string, name and wave parameters. The other types are less common.

The name parameter type is used to get the name of an object that is not part of Igor's data hierarchy, such as a symbolic path name or a picture name, or the name of an object to be created.

The doubleName parameter type is used to allow the user to specify a compound function name that includes a module name (e.g., MyModule#MyFunction) or a compound picture name (e.g., ProcGlobal#MyPicture).

The wave type is used to get a reference (handle) to an existing wave.

The waveRange parameter type is used to allow the user to specify an input wave or a subset of a 1D input wave, for example wave1(x1,x2) or wave1[p1,p2]. Igor's CurveFit operation is an example of an operation that supports this syntax.

The varName parameter type is used when a parameter must be the name of a local or global variable or NVAR or SVAR. This applies when an operation wants to return a value via a variable whose name is specified as a parameter. For example, Igor's Open operation takes a refNum parameter which is the name of a numeric variable, and stores a file reference number in the specified variable. VarName should not be used for normal input parameters – use number instead.

The dataFolderRef type is used to get a reference (handle) to an existing data folder.

The dataFolderAndName parameter type is typically used for operations that create waves. For example, Igor's Duplicate operation takes a destWave parameter. Since the destination wave may not exist when Duplicate runs, the destWave parameter can not be of type wave. Using a dataFolderAndName parameter allows the user to reference an object that does not yet exist.

The structure parameter type would be used by advanced programmers to pass pointers to structures between an Igor user-defined function and an XOP.

Optional Parameters

Optional parameters are designated using brackets. There are three types of optional parameters, as the following examples illustrate:

```
// Optional flag or keyword parameters
SampleOp /A[=<parameters>]
SampleOp key1[=<parameters>]
SampleOp key1[(<parameters>)]=<parameters>
```

```
// Normal optional parameters
SampleOp /A={number:n1 [,string:s1, wave:w1]}
SampleOp key1={number:n1 [,string:s1, wave:w1]}
SampleOp number:n1 [,string:s1, wave:w1]

// Array-style optional parameters
SampleOp /A={number:n1, string[3]:s1}
SampleOp key1={number:n1, string[3]:s1}
SampleOp number:n1, string[3]:s1
```

Using the optional flag or keyword syntax allows the user to supply or omit the equals sign and subsequent parameters after a flag or keyword. With a qualified keyword, it also allows the user to supply or omit the qualifier.

Using the normal optional parameter syntax allows you to designate that some parameters are required and the rest are optional. Do not nest sets of brackets for this purpose. Just one set is allowed.

Using the array-style optional parameter syntax allows you to specify that zero or more parameters of a particular type appear at the end of a parameter group or at the end of the main parameter list.

When creating a Save Wave type of operation, you can combine the 'as' keyword and the array-style optional parameters like this:

```
    Save wave[100]:waves as string
```

In this case at least one wave must be specified in the command before the ‘as’ keyword.

Similarly when creating a Display type of operation, you can combine the 'vs' keyword and the array-style optional parameters like this:

```
    Display wave[100]:waves vs wave:xWave  // vs requires Igor Pro 6.30 or later
```

In this case at least one wave must be specified in the command before the ‘vs’ keyword.

Other than the usages shown above, no other use of brackets to indicate optional parameters is allowed. For example, the brackets here are not needed or allowed:

```
SampleOp [ /A /B=number:n1 /C=string:s1 ] // WRONG
```

All flag and keyword groups are always optional. In other words, the user can always omit any flag or keyword and this fact is not to be indicated by brackets in the template.

As explained below, you can do a runtime check to see if a particular parameter group was supplied when the operation was invoked. You can also do a runtime check to see if an optional parameter within a group was supplied.

When the user invokes the operation, simple main parameters must appear in the order given by the command template if they appear at all. Flag groups and keyword groups can appear in any order.

If a flag or keyword group takes a prefix character (parenthesis, bracket, brace) and all of the parameters except the first are optional, Operation Handler will allow the user to invoke the group without the prefix character and with just one parameter. This allows you to change the syntax of a group from:

```
    /A=value or keyword=value
```

to

```
    /A={value1[, value2]} or keyword={value1[, value2]}
```

and yet to maintain backward compatibility. Old Igor procedure code that omits the prefix character will still work and new code that uses the prefix character will also work. At runtime, you test to see if the second parameter was provided.

Mnemonic Names

The mnemonic names that you provide in the template are used to automatically generate the source code for your runtime parameter structure. See **Creating Starter Code** on page 72. Each mnemonic name becomes the name of a field in the structure. Therefore mnemonic names in a given template must be distinct.

The Runtime Parameter Structure

When you create your starter code, Operation Handler defines a structure into which it will store parameters and other values at runtime. When your operation is invoked, Igor passes this structure to you.

The format of the runtime parameter structure is best understood through a simple example. Assume that your command template is:

```
SampleOp /A=number:aNum /B={string:bStrH,name:bName} /C=wave:cWaveH
            key1={number:key1Num,string:key1StrH},
            key2={name:key2Name,wave:key2WaveH}
```

To generate starter code you would pass this template to the ParseOperationTemplate operation:

```
   ParseOperationTemplate /C=6 /S=1 /T "<template here>"
```

If your operation is thread-safe, include the /TS flag in the ParseOperationTemplate command.

This stores starter code in the clipboard. The runtime parameter structure part of the starter code looks like this:

```
#pragma pack(2)                  // Igor structures are 2-byte-aligned.

struct SampleOpRuntimeParams {
   // Flag parameters.

   // Parameters for /A flag group.
   int AFlagEncountered;
   double aNum;
   int AFlagParamsSet[1];

   // Parameters for /B flag group.
   int BFlagEncountered;
   Handle bStrH;
   char bName[MAX_OBJ_NAME+1];
   int BFlagParamsSet[2];

   // Parameters for /C flag group.
   int CFlagEncountered;
   waveHndl cWaveH;
   int CFlagParamsSet[1];

   // Main parameters.

   // Parameters for key1 keyword group.
   int key1Encountered;
   double key1Num;
   Handle key1StrH;
   int key1ParamsSet[2];

   // Parameters for key2 keyword group.
   int key2Encountered;
   char key2Name[MAX_OBJ_NAME+1];
   waveHndl key2WaveH;
   int key2ParamsSet[2];

   // These are postamble fields that Igor sets.
   int calledFromFunction;       // 1 if called from a user-defined function.
   int calledFromMacro;          // 1 if called from a macro.
};
typedef struct SampleOpRuntimeParams SampleOpRuntimeParams;
typedef struct SampleOpRuntimeParams* SampleOpRuntimeParamsPtr;

#pragma pack()                // Reset structure alignment.
```

It is critical that the structure's fields match the command template that you pass to **RegisterOperation**. If you change the command template and fail to change the structure or vice versa, a crash will likely occur. Therefore it is best to use ParseOperationTemplate to regenerate the code for the structure after changing the command template as this guarantees that the template and structure will be consistent.

All structures passed between Igor and an XOP use two-byte packing. You must use the pragmas shown above to guarantee this.

You can use the calledFromFunction and calledFromMacro fields to determine how your operation was called, although this is usually not necessary.

For each parameter group, there will be a field to indicate if the group was encountered in the command, followed by a field for each parameter in the group, followed by an array that indicates which parameters in the group actually appeared in the command. In the example above, the BFlagEncountered will be non-zero if the command included a /B flag. The bStrH and bName fields contain the values specified for the parameters to the /B flag. The BParamsSet array contains an element for each parameter in the group and tells you if the corresponding parameter was present in the command.

For each parameter there is a corresponding field of the appropriate type in the runtime parameter structure:

Parameter Type	**Field Type**
number	double
string	Handle
name	char[MAX_OBJ_NAME+1]
doubleName	char[MAX_LONG_NAME+1]
wave	waveHndl
waveRange	WaveRange structure
varName	char[MAX_OBJ_NAME+1]
dataFolderRef	DataFolderHandle
dataFolderAndName	DataFolderAndName structure
structure	pointer to structure

NOTE: At runtime, the handles corresponding to string, wave and dataFolderRef parameters can be NULL as can the pointer corresponding to a structure parameter. This can happen if the caller passes an uninitialized reference or a reference whose initialization failed to you. It can also happen if the caller passes * for the parameter which signifies “default”. Your code must test for NULL parameters as described in the following sections.

These parameter fields are arranged in groups that correspond to parameter groups.

In the example above, BParamsSet[0] tells you if the string parameter to /B was specified and BParamsSet[1] tells you if the name parameter to /B was specified. In this example, all of the parameters in the group are required, so, if BFlagEncountered is non-zero then BParamsSet[0] and BParamsSet[1] are guaranteed to also be non-zero and you don't need to test them. You would test the BParamsSet array elements if the /B flag had optional parameters. The number of elements in the ParamSet array must match the total number of parameters in the parameter group, including any optional parameters.

If your command template includes a flag or keyword with no parameters then there will be just one field for that group - the field that tells you if the flag or keyword was encountered in the command. For example, if the command template includes

```
/A
```

this is represented in the runtime parameter structure as:

```
// Parameters for /A flag group.
int AFlagEncountered;
```

When used in a flag or keyword group, a set of array-style optional parameters is represented as an array in the structure. For example, if the command template contains

```
key3={string:key3StrH,number[2]:key3Num}
```

this is represented in the runtime parameter structure as:

```
int key3Encountered;
Handle key3StrH;
double key3Num[2];         // Optional parameter.
int key3ParamsSet[3];
```

When used as a simple main parameter, a set of array-style optional parameters is also represented as an array in the structure. For example, if the command template ends with

```
string:strH, number[2]:num
```

this is represented in the runtime parameter structure as:

```
// Parameters for simple main group #0.
int strHEncountered;
Handle strH;
int strHParamsSet[1];

// Parameters for simple main group #1.
int numEncountered;
double num[2];             // Optional parameter.
int numParamsSet[2];
```

At runtime, Operation Handler sets the "Encountered" field for each parameter group to sequential values starting from 1, indicating the order in which parameter groups were encountered. For most operations this order is immaterial and all you care about is if the field is zero or non-zero.

Each flag parameter group can be set only once by a single command. Operation Handler returns an error if a command tries to use a given flag group twice.

Igor Pro 6.30 and later allow a command to use the same keyword multiple times if all keyword parameters are array-style parameters. Previous versions of Igor treated this as an error. If all keyword parameters are array-style parameters with n elements, a single command can use the keyword up to n times. Operation Handler generates an error if the keyword is used more than n times.

For keyword parameter groups, if the same keyword is used more than once, the Encountered field will reflect the first occurrence of the keyword and there will be gaps in the sequence.

Qualified Keywords

Igor Pro 6.30 and later support "qualified" keywords. For example:

```
ModifyGraph mode = 3           // Unqualified: Set all traces to markers mode
ModifyGraph mode(wave0) = 3    // Qualified: Set wave0 only to markers mode
```

Here wave0 is the "qualifier". It narrows the scope of the mode keyword.

The qualifier can consist of any number of parameters of any type. It appears in parentheses immediately after the keyword. You can not use brackets or braces to introduce the qualifier.

The entire qualifier can be optional. If the qualifier consists of more than one parameter, all parameters after the first can be optional.

In the general case, the template for a qualified keyword looks like this:

```
SampleOp keyword[(<qualifier1>[,<qualifier2>])] [= {<value1>[,<value2>]]
```

Any pair of brackets can be omitted in which case the corresponding element will be required rather than optional.

The **first** left bracket and its matching right bracket make the entire qualifier optional.

The **second** left bracket and its matching right bracket make the second parameter of the qualifier optional.

The **third** left bracket and its matching right bracket make the entire righthand side optional.

The **fourth** left bracket and its matching right bracket make the second righthand parameter optional.

You can make the entire qualifier optional but the first parameter of the qualifier can not be optional:

```
// OK - Entire qualifier optional
SampleOp key1[(number:num1,number:num2)]

// OK - Second qualifier parameter optional
SampleOp key1[(number:num1[,number:num2])]

// Bad - First qualifier parameter can not be optional
SampleOp key1[([number:num1,number:num2])]
```

In addition to normal optional parameters, you can use array-style optional parameters:

```
ModifyGraph mode[(name[10]:traceName)] = {number[10]:modeCode}
```

If the qualifier is required and the only qualifier parameter is an array-style optional parameter, as in this template:

```
SampleOp key1(number[3]:array)      // Array-style optional parameter
```

then you an invoke the operation with no parameters:

```
SampleOp key1                       // Bad - qualifier required
SampleOp key1()                     // OK - no parameters
SampleOp key1(1)                    // OK - one parameter
SampleOp key1(1,2)                  // OK - two parameters
SampleOp key1(1,2,3)                // OK - three parameters
```

When all keyword parameters are array-style optional parameters, there are two ways to specify the qualifier when invoking the operation. Using the ModifyGraph example:

```
ModifyGraph mode(wave0,wave1) = {3,4}      // Set mode for two traces
ModifyGraph mode(wave0)=3, mode(wave1)=4   // Set mode for two traces
```

Both commands return the following via the runtime parameter structure:

```
traceName[0]: wave0
traceName[1]: wave1
```

```
traceNameParamsSet[0]=1, traceNameParamsSet[1]=1
modeCode[0]: 3
modeCode[1]: 4
modeCodeParamsSet[0]=1, modeCodeParamsSet[1]=1
```

All other elements of traceNameParamSet and modeCodeParamSet will be 0.

It is permitted to use the same keyword twice in a single command only if all keyword parameters are array-style parameters.

The user may invoke the operation like this:

```
ModifyGraph mode(wave0,wave1) = 3
```

In this case, two elements of the traceName array in the runtime parameter structure will be set but just one element of the modeCode array will be set. You can choose to treat this as if the user executed:

```
ModifyGraph mode(wave0)=3, mode(wave1)=3
```

or you can consider this an error and return an error code. Your code should not assume that the same number of parameters were passed for both array-style parameters.

String Parameters

Each string parameter is passed to you in a handle. The handle for a string parameter can be NULL. This would happen if, for example, the user used an SVAR reference to pass the contents of a global string variable to you and the global string variable did not exist at runtime. You must always test a string handle. If it is NULL, do not use it. If the string is required for the operation, return the USING_NULL_STRVAR error code.

IMPORTANT

Do not dispose string parameter handles. Also do not access string parameter handles after your ExecuteOperation function returns. Igor will dispose them automatically when your ExecuteOperation function returns.

If you want to retain string data for later use, you must make your own copy of the string handle, using the **WMHandToHand** function or copy the string to a C string using **GetCStringFromHandle**. In this regard, external operations and external functions work differently. In an external operation, you must **not** dispose string parameter handles. In an external function, you must dispose them.

String handles are not C strings and are not null-terminated. Use **WMGetHandleSize** to determine the number of characters in the string. You can use the GetCStringFromHandle XOPSupport routine to move the characters into a C string. See **Understand the Difference Between a String in a Handle and a C String** on page 221 for further discussion.

Name Parameters

Igor names consist of MAX_OBJ_NAME characters. An example of a name parameter is the name of an Igor symbolic path in a /P=pathName flag. The user can specify a name parameter as $"", in which case the corresponding name field of the runtime parameter structure will be an empty string. Usually, an operation treats this the same as if the parameter were not specified in the command.

Double Name Parameters

Double names are rarely used so most XOPs will not need to use this type of parameter.

Igor double names are used for combining a module name and a function or proc pict name in one compound name, for example, MyModule#MyProcPict. They consist of up to MAX_LONG_NAME characters.

The user can specify a double name parameter as $"", in which case the corresponding name field of the runtime parameter structure will be an empty string. Usually, an operation treats this the same as if the parameter were not specified in the command.

When running in an independent module, if a simple name is specified for a doubleName parameter, Igor automatically prepends the independent module name. For example, if a function is running in an independent module named MyIndependentModule and it executes:

```
SampleOp functionName=MyFunction
```

you receive "MyIndependentModule#MyFunction" as the parameter.

As of XOP Toolkit 8 and Igor Pro 8, MAX_LONG_NAME is the same as MAX_OBJ_NAME - both equate to 255.

Wave Parameters

Waves are passed to you as wave handles of type waveHndl. Wave handles always belong to Igor. You must never dispose or directly modify a wave handle. You operate on a wave by passing its handle to an XOPSupport routine.

The handle for a wave parameter can be NULL. This would happen, for example, if the user passed an uninitialized wave reference (WAVE) or a wave reference whose initialization failed to your operation. You must always test a wave handle. If it is NULL, do not use it. If the wave is required for the operation, return a NULL_WAVE_OP error code.

The user can use * in place of a wave name when a wave parameter is expected. This will result in a null wave handle in the runtime parameter structure. If the wave is required for the operation, return a NOWAV error code. Otherwise, interpret this to mean that the user wants default behavior.

You must make sure that you can handle the data type of the wave. For example, if your operation requires a numeric wave, you must return an error if passed a text wave. Also check the numeric type and dimensionality if appropriate. See the **WaveType** and **MDGetWaveDimensions** functions.

Wave Range Parameters

Wave range parameters allow the user to specify a range of a 1D wave. They are passed to you as WaveRange structures. This structure is defined in IgorXOP.h:

```
struct WaveRange {
   waveHndl waveH;
   double startCoord;          // Start point number or x value
   double endCoord;            // End point number or x value
   int rangeSpecified;         // 1 if user specified range.
   int isPoint;                // 0: X values. 1: Points.
};
```

The waveH field can be NULL. If it is, you should return NULL_WAVE_OP, unless you want to allow a null wave. As with the wave parameter, the user can use * in place of the wave name in which case the waveH field will be NULL. Also as with the wave parameter, you must check the wave's type to make sure it is a type you can handle. See **WaveType**.

waveH is treated as 1D regardless of its actual dimensionality.

If the rangeSpecified field is zero, then the command did not specify a range of the wave. In this case, the isPoint field will be non-zero, the startCoord field will contain zero and the endCoord field will contain the number of the last point in the wave.

If the rangeSpecified field is non-zero then the command did specify a range. If isPoint is non-zero then startCoord and endCoord will contain point numbers. If isPoint is zero then startCoord and endCoord will contain X values.

Regardless of how the command was specified, you can use the **CalcWaveRange** routine to find the point numbers of the range of interest like this. This example assumes that the runtime parameter structure contains a WaveRange field named source.

```
IndexInt startPoint, endPoint;
int direction;

startPoint = p->source.startCoord;
endPoint = p->source.endCoord;
direction = 1;
if (p->source.rangeSpecified) {
   WaveRangeRec wr;

   MemClear(&wr,sizeof(WaveRangeRec));
   wr.x1 = p->source.startCoord;
   wr.x2 = p->source.endCoord;
   wr.rangeMode = 3;
   wr.isBracket = p->source.isPoint;
   wr.gotRange = 1;
   wr.waveHandle = p->source.waveH;
   wr.minPoints = 2;
   if (err = CalcWaveRange(&wr))
      return err;

   startPoint = wr.p1;
   endPoint = wr.p2;
   direction = wr.wasBackwards ? -1:1;
}
```

VarName Parameters

A varName parameter is used in rare situations when the parameter to an operation is the name of a numeric or string variable into which the operation is to store a value. For example, an operation that opens a file can return a file reference number via a varName parameter, as Igor's Open operation does.

When invoking an operation with a varName parameter, the user can pass the name of a global variable, the name of a local variable, or, when executing from a user-defined function, the name of an NVAR or SVAR.

When called from the command line or from a macro, the varName field in the runtime parameter structure contains an actual variable name. When called from a user-defined function, it actually contains binary data that Igor uses to locate the local variable, NVAR or SVAR into which data is to be stored. Consequently you should never use the value of the varName field except to pass it to XOPSupport routines designed to handle it as described in this section.

At runtime you can determine the type of the variable by calling **VarNameToDataType** which returns numeric (NT_FP64), complex numeric (NT_FP64 | NT_CMPLX) or text (0).

To store a value in a variable referenced by a varName parameter, you must use the **StoreNumericDataUsingVarName** or **StoreStringDataUsingVarName** XOPSupport functions. These call back to Igor which knows how to store into global variables, local variables, NVARs and SVARs.

In Igor Pro 6.10, the ability to retrieve values from numeric and string variables was added through the **FetchNumericDataUsingVarName** and **FetchStringDataUsingVarName** XOPSupport functions. These can be used to implement external operation parameters that function both as inputs and outputs. For example, you would use FetchNumericDataUsingVarName to retrieve the initial value of a numeric parameter and StoreNumericDataUsingVarName to set its final value. For clarity however, in general it is better to keep inputs and outputs separate.

Using a VarName parameter allows you to create a parameter whose type is not determined until runtime. The user can pass either a numeric variable or a global variable for the parameter. However this technique is obscure and should be avoided if at all possible.

You can call VarNameToDataType to determine which type was passed. This type flexibility is unique to varName parameters and may be of use in rare cases.

VarName should not be used for normal input parameters – use number instead.

Data Folder Reference Parameters

Data folder references are passed to you as data folder handles of type DataFolderHandle. The calling code can pass a literal data folder path (root:MyFolder), a $ followed by a string containing a data folder path, or a data folder reference variable (DFREF).

Data folder handles always belong to Igor. You must never dispose or directly modify a data folder handle. You operate on a data folder by passing its handle to an XOPSupport routine.

The handle for a data folder reference parameter can be NULL. This would happen, for example if the user passed an uninitialized data folder reference (DFREF) or a data folder reference whose initialization failed to your operation. You must always test a data folder handle. If it is NULL, do not use it. If the data folder reference is required for the operation, return a NULL_DATAFOLDER_OP error code.

The user can use * in place of a data folder reference when a data folder parameter is expected. This will result in a null data folder handle in the runtime parameter structure. If the data folder is required for the operation, return a NULL_DATAFOLDER_OP error code. Otherwise, interpret this to mean that the user wants default behavior.

DataFolderAndName Parameters

A dataFolderAndName parameter is used when you need to get the name and location of a wave that may not yet exist. For example, the Duplicate operation takes a source wave and a destination wave name. The destination wave may or may not already exist when Duplicate is invoked.

A dataFolderAndName parameter can also be used to get the name of an existing data folder or the name of a data folder to be created.

The runtime parameter structure contains a DataFolderAndName structure for a corresponding dataFolderAndName parameter. The DataFolderAndName structure is defined in IgorXOP.h:

```
struct DataFolderAndName {
   DataFolderHandle dfH;
   char name[MAX_OBJ_NAME+1];
};
```

Typically the dfH and name fields of this structure would be passed to **GetOperationDestWave** to create a destination wave as shown in the example below.

Destination Waves and Wave References

The DataFolderAndName type parameter is often used to allow the user to specify the name of the operation's destination wave through a /DEST=<destwave> flag. Traditionally, when an operation that allows you to specify a destination wave is compiled into a user-defined function, if the user uses a simple name for the destination wave, the Igor compiler automatically creates a wave reference in the function for that wave. For example, if you write this:

```
Duplicate wave0, wave1
```

the Igor compiler automatically creates a wave reference for wave1, as if you wrote:

```
Duplicate wave0, wave1
Wave wave1
```

This automatic local wave reference is created only if the user uses a simple name, not if the user uses $"<string>", a partial data folder path or a full data folder path.

The DataFolderAndName type parameter allows you to do the same thing, but you have to use special syntax when writing the operation template. Consider this operation template:

```
SampleOp DataFolderAndName:{dest,real}
```

This template declares a DataFolderAndName parameter with a mnemonic name "dest" which, when compiled into a user-defined function, automatically creates a wave reference for the destination wave, if the user uses a simple name. The "real" keyword specifies the type of the destination wave. Other options are "complex", "text", “wave” and “dfref”. “wave” and “dfref” require Igor Pro 6.22 or later.

If a wave reference for the specified destination already exists when the operation is compiled, it will not attempt to create a new wave reference. This allows the Igor programmer to indicate the actual type of the destination wave for those operations, such as FFT, in which the destination wave can be of different types depending on operation parameters.

See the documentation for Igor's DWT operation for an example of how to document this automatic creation of wave references.

If your operation can create a destination wave of different types depending on circumstances, you should pick the most likely type. See the documentation for Igor's FFT operation for an example of how to document this behavior.

Using the special syntax shown above causes Igor to create an automatic wave reference under the conditions explained above. However, the automatic wave reference will be NULL until you set it by calling SetOperationWaveRef as shown in the example below.

The SetOperationWaveRef callback sets the automatically created wave reference to refer to a specific wave, namely the wave that you created in response to the DataFolderAndName parameter. You must call it after successfully creating the destination wave.

SetOperationWaveRef does nothing if no automatic wave reference exists.

DataFolderAndName Destination Wave Example

This section presents an example of an operation that has a destination wave parameter. It uses the **GetOperationDestWave** callback to do most of the work. GetOperationDestWave handles all of the following:

- Recognizing a wave reference passed as the destination wave
- Creating a new wave if the destination wave does not already exist
- Overwriting or changing the dimensions and data type of the destination wave if it already exists

In addition, the **SetOperationWaveRef** call in the sample code below sets the automatic output wave reference, if appropriate, when called from a user-defined function.

The example operation is defined by this Operation Handler template:

```
SampleOp /DEST=DataFolderAndName:{dest,real}
```

This results in an operation runtime parameter structure containing:

```
   int DESTFlagEncountered;
   DataFolderAndName dest;
   int DESTFlagParamsSet[1];
```

In the following code, p is a pointer to the operation runtime parameter structure.

```
   waveHndl destWaveH;                  // Destination wave handle.
   int destWaveRefIdentifier;           // Identifies a wave reference
   char destWaveName[MAX_OBJ_NAME+1];
   DataFolderHandle dfH;
   int dataType;
   CountInt dimensionSizes[MAX_DIMENSIONS+1];
   int options;
   int err;

   destWaveH = NULL;
   destWaveRefIdentifier = 0;

   strcpy(destWaveName, "W_SampleOp"); // Default dest wave name
   dfH = NULL;                          // Default is current data folder

   dataType = NT_FP64;
   MemClear(dimensionSizes, sizeof(dimensionSizes));
   dimensionSizes[ROWS] = 100;

   if (p->DESTFlagEncountered) {
      strcpy(destWaveName, p->dest.name);
      dfH = p->dest.dfH;
      // If a wave reference was used, p->destParamsSet[0] contains
      // information that GetOperationDestWave uses to find it.
      destWaveRefIdentifier = p->DESTFlagParamsSet[0];
   }

   options = kOpDestWaveOverwriteOK | kOpDestWaveOverwriteExistingWave;

   err = GetOperationDestWave(dfH, destWaveName, destWaveRefIdentifier,
         options, dimensionSizes, dataType, &destWaveH, NULL);
   if (err != 0)
      return err;

   <Store output data in dest wave using destWaveH>
   WaveHandleModified(destWaveH);

   // Set wave reference to refer to destination wave.
   if (destWaveRefIdentifier != 0)
      SetOperationWaveRef(tp, destWaveH, destWaveRefIdentifier);
```

The GetOperationDestWave callback creates the destination wave if it does not exist and overwrites it if it does.

For further details, see **GetOperationDestWave** on page 237.

DataFolderAndName Data Folder Example

You can also use a DataFolderAndName parameter to get the name of a data folder rather than a wave. In this case, the dfH field of the DataFolderAndName structure will contain the parent data folder handle and the name field will contain the name of the child data folder which may or may not exist.

The root data folder is a special case. If the root is specified in the command then the dfH field will contain the root data folder handle and the name field will be empty.

Here is code that gets a handle for an existing data folder and takes the special case into account:

```
   dataFolderH = p->df.dfH;
   if (dataFolderH == NULL)
      return EXPECT_DATAFOLDER_NAME;
   if (p->df.name[0] != 0) {
      if (err = GetNamedDataFolder(dataFolderH, p->df.name, &dataFolderH))
         return err;
   }
```

Structure Parameters

An external operation can take a structure as a parameter. This is a technique for advanced programmers.

Structure parameters are passed as pointers to structures. These pointers always belong to Igor. You must never dispose or resize a memory block using a structure pointer but you may read and write its fields.

Igor structures are always two-byte-aligned. As the example below shows, you must use the pack pragma to make sure that your C structure is also two-byte-aligned. See **Structure Alignment** on page 193 for details on structure alignment.

An instance of an Igor structure can be created only in a user-defined function and exists only while that function is running. Therefore, when a structure must be passed to an external operation, the operation must be called from a user-defined function, not from the command line or from a macro. An external operation that has an optional structure parameter can be called from the command line or from a macro if the optional structure parameter is not used.

The pointer for a structure parameter can be NULL. This would happen if the user supplies * as the parameter or in the event of an internal error in Igor. Therefore you must always test a structure parameter to make sure it is non-NULL before using it.

If you receive a NULL structure pointer as a parameter and the structure is required for the operation, return an EXPECTED_STRUCT error code. Otherwise, interpret this to mean that the user wants default behavior.

Here is an example of a command template that specifies a structure parameter:

```
   DemoStructOp structure:{sp,DemoStruct}
```

In this example, “structure” is the parameter type, “sp” is the parameter name and “DemoStruct” is the name of the type of structure expected. When Igor compiles a call to your operation, it will require that the structure passed as a parameter be of the specified type. Thus, users of this operation are forced to declare a structure type named DemoStruct. Choose a structure type name that is distinctive and unlikely to be used for any other purpose.

Although Igor requires that the structure passed to your operation is of the specified type, it does not guarantee that the programmer calling your operation has defined the structure properly. If the structure definition used by the Igor procedure programmer is inconsistent with the structure defined in your C code, a crash is likely to occur. You can increase the likelihood that the structure will be correct by providing an Igor procedure file that defines it. It is also a good idea to include a version field in your structure as illustrated in the next section.

In very rare cases, you might want to define an operation that takes any type of structure. For example, in implementing a sophisticated curve fitting algorithm, you might define a structure to be passed to your operation that starts with certain fields and contains other user-defined fields afterwards. Your operation accesses the known fields and passes the entire structure to a user-defined function which accesses the whole structure. If you specify void as the structure type (e.g., "void" instead of "DemoStruct"), Igor will allow the user to pass any type of structure to your operation.

In some cases you might need to know the total size of a structure passed to your operation, for example, if your operation writes a user-defined structure to a file. For this, use the extended form of the structure parameter, described under **Extended Structure Parameters** on page 90.

Wave Handles In Structures

Usually a waveHndl field in a structure is used to pass a wave reference from Igor to your XOP. However, it can also be used to pass a wave reference from your XOP to Igor.

If you store a wave handle in a waveHndl field of a structure you need to inform Igor by calling **HoldWave** on the structure field. By doing this, you maintain the integrity of Igor's internal wave reference count. For details see **Wave Reference Counting** on page 131.

Data Folder Handles In Structures

Usually a DataFolderHandle field in a structure is used to pass a data folder reference from Igor to your XOP. However, it can also be used to pass a data folder reference from your XOP to Igor.

If you store a data folder handle in a DataFolderHandle field of a structure you need to inform Igor by calling **HoldDataFolder** on the structure field. By doing this, you maintain the integrity of Igor's internal data folder reference count. For details see **Data Folder Reference Counting** on page 143.

External Operation Structure Parameter Example

Here is Igor procedure code which passes a structure to an external operation.

```
Constant kDemoStructVersion = 1000

Structure DemoStruct        // Structure of parameter to DemoStructOp.
   uint32 version           // Structure version.
   double num
   String str
EndStructure

Function TestDemoStructOp()
   String tmp

   STRUCT DemoStruct s

   s.version = kDemoStructVersion
   s.num = 1
   s.str = "Testing structure parameter"

   DemoStructOp s
End
```

Here is C code that implements the external operation. Most of this code would be automatically generated by Operation Handler when you execute this command within Igor:

```
ParseOperationTemplate/T/S=1/C=6 "DemoStructOp structure:{sp,DemoStruct}"

#pragma pack(2)                    // Igor structures are 2-byte-aligned.
#define kDemoStructVersion 1000    // 1000 means 1.000.
struct DemoStruct {
   UInt32 version;                 // Structure version.
   double num;
   Handle strH;
};
typedef struct DemoStruct DemoStruct;
#pragma pack()                     // Reset structure alignment.

// Operation template: DemoStructOp structure:sp

// Runtime param structure for DemoStructOp operation.
#pragma pack(2)                    // Igor structures are 2-byte-aligned.
struct DemoStructOpRuntimeParams {
   // Parameters for simple main group #0.
   int spEncountered;
   DemoStruct* sp;
   int spParamsSet[1];

   // These are postamble fields that Igor sets.
   int calledFromFunction;
   int calledFromMacro;
};
typedef struct DemoStructOpRuntimeParams DemoStructOpRuntimeParams;
typedef struct DemoStructOpRuntimeParams* DemoStructOpRuntimeParamsPtr;
#pragma pack()                    // Reset structure alignment.

extern "C" int
ExecuteDemoStructOp(DemoStructOpRuntimeParamsPtr p)
{
   DemoStruct* sp;
   char buf[256];
   char str[128];
   int err = 0;

   sp = NULL;

   // Flag parameters.

   if (p->spEncountered)
      sp = p->sp;

   if (sp == NULL) {
      strcpy(buf, "sp is NULL" CR_STR);
   }
   else {
      if (sp->version != kDemoStructVersion) {
         err = INCOMPATIBLE_STRUCT_VERSION;
         goto done;
      }
      if (err = GetCStringFromHandle(sp->strH, str, sizeof(str)))
         goto done;
      sprintf(buf, "sp->num = %g, sp->strH = \"%s\"", sp->num, str);
   }
   XOPNotice(buf);

done:
   return err;
}

int
RegisterDemoStructOp(void)
{
   char* cmdTemplate;
   char* runtimeNumVarList;
   char* runtimeStrVarList;

   cmdTemplate = "DemoStructOp structure:{sp,DemoStruct}";
   runtimeNumVarList = "";
   runtimeStrVarList = "";
   return RegisterOperation(cmdTemplate, runtimeNumVarList,
               runtimeStrVarList, sizeof(DemoStructOpRuntimeParams),
               (void*)ExecuteDemoStructOp, 0);
}
```

The Igor procedure code must declare a DemoStruct structure and the C code must declare a matching C structure. The use of the version field is a convention for preventing a crash if the procedure version of the structure and the C version get out-of-sync.

The Igor code declares the DemoStruct structure. It then creates and initializes an instance of it, named s. It then passes s (actually a pointer to s) to the DemoStructOp external operation.

The DemoStructOp external operation first checks that a valid pointer has been passed. It then checks that the version of the structure is compatible before accessing its fields. It can read, write or read and write any of the fields.

An advanced programmer may want to use a more flexible versioning scheme by allocating reserved fields in the structure and then using the version field to handle whatever version of the structure was passed from the Igor procedure. If possible you should simplify your life by using the simplified versioning technique shown above. However, if you decide to save structure data to disk and later read it back, you will have to deal with more complex versioning issues, as well as cross-platform byte-order issues. You will also have to deal with versioning issues if your XOP will be used by many people and you can not force them to update their Igor procedure code when you update your XOP.

For further important details see **Using Igor Structures as Parameters** on page 194.

Extended Structure Parameters

An extended form of the structure parameter allows you to determine the size and structure type name of the structure passed to the XOP. The main reason for adding this feature was to make it possible to create an operation that could accept any type of structure and write its contents to a file. This requires that we know the size of the structure.

The extended form of the template is:

```
   DemoStructOp structure:{s,void,1}
```

Here s is the mnemonic name for a structure parameter, void signifies that your operation accepts any type of structure, and 1 signifies that you want this to be an extended structure parameter.

When this form is used, the runtime parameter structure passed to the your operation's Execute routine contains a field of type IgorStructInfo instead of a pointer to the actual parameter. The IgorStructInfo structure contains fields that indicate the size of the structure parameter, the structure type name and a pointer to the structure parameter itself.

You should use the extended form if you want the added robustness provided by comparing the size and type name of the structure parameter passed to you to the expected size and type name. Another reason is to accept a structure parameter of any type, for example so that you can write it to a file.

If the user supplies * as the parameter for an extended form structure, the structSize field of the IgorStructInfo structure will be zero and the structPtr field will be NULL. You must test for this.

Extended Structure Parameter Example

The code to implement the extended form structure parameter is the same as shown above except for the differences listed here.

The command template is slightly different:

```
ParseOperationTemplate/T/S=1/C=6 "DemoStructOp structure:{s,DemoStruct,1}"
```

The runtime parameter structure will have an IgorStructInfo field:

```
struct DemoStructOpRuntimeParams {
   // Parameters for simple main group #0.
   int sEncountered;
   IgorStructInfo s;       // Contains info about the structure parameter
   int sParamsSet[1];
```

The Execute operation will use the fields of the IgorInfoStruct:

```
extern "C" int
ExecuteDemoStructOp(DemoStructOpRuntimeParamsPtr p)
{
   IgorStructInfo* isip;
   DemoStruct* sp;
   char buf[256];
   char str[128];
   int err = 0;

   sp = NULL;

   // Flag parameters.

   if (p->sEncountered) {
      isip = &p->s;                 // Point to IgorStructInfo field.
      if (isip->structSize > 0) {   // 0 means user passed * for param.
         if (isip->structSize = sizeof(DemoStruct)) {
            err = OH_BAD_STRUCT_SIZE;
            goto done;
         }

         if (CmpStr(isip->structTypeName,"DemoStruct") != 0)) {
            err = OH_BAD_STRUCT_TYPE_NAME;
            goto done;
         }

         sp = p->sp;
      }
   }

   . . .    // The rest is the same as the previous example.
```

In this case there is no point to testing the structTypeName field since we specified that only structures of type DemoStruct could be passed to our operation. The structTypeName field may be of use in cases where any type of structure can be passed as the parameter.

Runtime Output Variables

Some operations create numeric and/or string variables to pass information back to the calling routine. For example, the CurveFit operation creates V_chisq and V_Pr, among others. When an operation is called from a user-defined function the operation creates local variables (unless the obsolete rtGlobals=0 mode is in effect). When invoked from macros, it creates local variables. When invoked from the command line, it creates global variables.

If you want to create runtime output numeric variables, you need to pass a semicolon-separated list of variable names as the runtimeNumVarList parameter to **RegisterOperation**. Numeric variable names must be legal standard Igor names and must begin with "V_". When your operation executes, you must call **SetOperationNumVar** to store a value in the variable. SetOperationNumVar takes care of determining if a local or global variable is set.

Creating a runtime output string variable is the same except that you use the runtimeStrVarList parameter to RegisterOperation, string variable names must start with "S_", and you use **SetOperationStrVar** to store a value in the variable.

File-loader operations should set the standard output variables V_flag, S_fileName, S_path and S_waveNames. These output variables must be declared when calling RegisterOperation. For example, the RegisterOperation function for SimpleLoadWave contains these statements:

```
   runtimeNumVarList = "V_flag;";
   runtimeStrVarList = "S_path;S_fileName;S_waveNames;";
```

You can set the file-loader output variables by calling **SetFileLoaderOutputVariables** from your Execute-Operation function.

Operations should not use the value of variables as inputs. All inputs should be specified through operation parameters. There is no provision for an operation to test the value of a local variable at runtime.

Starter Code Details

As explained on page 72, the starter code that Operation Handler generates for you includes the following:

- A comment showing the operation template
- A complete runtime parameter structure
- A skeleton ExecuteOperation function that you need to fill out
- A mostly complete RegisterOperation function which you need to call from your XOPMain function

The ExecuteOperation should be declared `extern "C"` if you are writing a C++ XOP and `static` if you are writing a C XOP. For example:

```
extern "C" int       // C++ - Generated by ParseOperationTemplate /C=6
ExecuteXOP1(XOP1RuntimeParamsPtr p)

static int           // C - Generated by ParseOperationTemplate /C=2
ExecuteXOP1(XOP1RuntimeParamsPtr p)
```

`extern "C"` is required in C++ code because all calls between Igor and the XOP use C calling conventions. See **C++ Code Called From C Code** on page 206 for details.

When filling out the ExecuteOperation function, remember that you need to test string, wave and data folder reference handle parameters to make sure they are not null. It is a good idea to examine a completed ExecuteOperation function from a sample WaveMetrics XOP to see how NULL handles are handled.

The RegisterOperation function call generated by ParseOperationTemplate is complete except that you may need to add runtime numeric or string output variables as described under **Runtime Output Variables** on page 91.

For a more elaborate example which generates templates for multiple external operations, see “VDT2 Templates.pxp”.

In the unlikely event that your command template exceeds 2048 characters, you will get an error in Visual C++. This is because of a line length limitation in Visual C++. You will need to break your command template up. See the NIGIPB2:NI488.cpp file for an example.

Updating Starter Code

If you change your operation syntax, for example to add a new parameter, you must regenerate your starter code and transfer the new code to your source file. If you have started to fill out your ExecuteOperation function, you can not merely overwrite your old starter code. You need to preserve any additions you have made. Here is the recommended way to do this:

1. Open your template experiment and add the new parameter to your function.
2. Run your function to regenerate the starter code.

3. In your development system, paste the new starter code into a new window.
4. Copy the template comment and the runtime parameter structure, which you presumably have not modified, in their entirety from the new starter code and paste into your source file, overwriting the corresponding old code.
5. Copy the RegisterOperation from the new starter code and paste into your source file, overwriting the old code, except that, if you have specified runtime output variables, you must preserve those statements.
6. Find the section of the new ExecuteOperation function that deals with the new parameter and add that section to your old ExecuteOperation function.

Thread-Safe External Operations

Multithreading makes it possible to utilize more than one processor on a multi-processor computer. Even on a single processor machine it allows multiple processes to run independent of one another.

Igor supports thread-safe external operations with certain restrictions discussed below. This section tells you how to convert a normal external operation to a thread-safe operation using the XOP1 XOP as an example.

Writing thread-safe code is trickier than writing regular code. For example, your operation can not write to a global variable because two instances of your operation might write different values to the global and interfere with each other's operation. Many web sites explain what "thread-safe" means and what you can and can not do in thread-safe code.

Changes for Thread-Safe External Operations

A few changes are needed to make an external operation thread-safe. In this section we illustrate these changes using the XOP1 external operation as an example.

Here are the steps for making the XOP1 external operation thread-safe:

1. Open the "XOP1 Template.pxp" experiment. In the procedure window, add the /TS flag to the ParseOperationTemplate command. This tells ParseOperationTemplate that your external operation is thread-safe.
2. Run the CreateXOP1StarterCode function to put new starter code in the clipboard. Go into your development system and paste the starter code into an empty text window.
3. In the XOP1.cpp source file, replace the runtime parameter structure with the new version just generated. The only difference is that the new version has an extra field:

   ```
   UserFunctionThreadInfoPtr tp;
   ```

   You do not have to do anything with this field but it must be there for a thread-safe external operation.
4. In the newly-generated starter code, find the call to RegisterOperation at the very bottom. Copy it to the clipboard and paste it over the old call to RegisterOperation in XOP1.cpp. The only difference is that the new code passes the kOperationIsThreadSafe flag as the last parameter when calling RegisterOperation.
5. For Macintosh, in the XOP1.r file, add threadSafeOp to the operation category:

   ```
   resource 'XOPC' (1100) {
       {
           "XOP1",
           waveOP+XOPOp+compilableOp+threadSafeOp,
       }
   };
   ```

6. For Windows, in the XOP1WinCustom.rc file, add threadSafeOp to the operation category:

   ```
   1100 XOPC
   BEGIN
   ```

```
      "XOP1\0",
      utilOp | XOPOp | compilableOp | threadSafeOp,

      "\0"
   END
```

When you make your own external operation thread-safe, check to make sure that it does not do anything that is not thread-safe.

Assuming that you have compiled a thread-safe version of XOP1, here is an example of how you could call it:

```
ThreadSafe Function AddOneToWave(w)
   Wave w

   XOP1 w            // Add one to wave
End

Function TestXOPInThread()
   // Create sample data
   if (!WaveExists(wave0))
      Make/O/N=10 wave0=p, wave1=p, wave2=p
   endif

   Variable numThreads = 3

   Variable mt = ThreadGroupCreate(numThreads)
   Variable i

   for(i=0; i<numThreads;)
      for(i=0; i<numThreads; i+=1)
         String name
         sprintf name, "wave%d", i
         Wave w = $name
         ThreadStart mt, i, AddOneToWave(w)     // Start thread
      endfor

      // Wait for threads to finish
      do
         Variable tgs = ThreadGroupWait(mt,100)
      while (tgs != 0)
   endfor

   Variable result = ThreadGroupRelease(mt)
   return result
End
```

More on Multithreading

For additional discussion of multithreading in XOPs see **Multithreading** on page 159.

Operation Handler Checklist

If your operation crashes or otherwise behaves unexpectedly, here are some things to double-check:

- You have set the compilableOp bit in the XOPC resource for your operation. If you have multiple operations, this bit must be set for each operation for which you want to use Operation Handler.

  If your operation is thread-safe, make sure that you have used the threadSafeOp in the category field of the XOPC resource and that you have passed the kOperationIsThreadSafe flag to **RegisterOperation** and that your runtime parameter structure has a UserFunctionThreadInfoPtr field. Also make sure that you do not do any non-thread-safe callbacks to Igor and that your code is written in a thread-safe fashion.

- You do not have a call to **SetXOPType**(TRANSIENT) in your code.
- Your runtime parameter structure must be consistent with your command template. Reread the section entitled **The Runtime Parameter Structure** on page 77. See **Creating Starter Code** on page 72 and **Updating Starter Code** on page 92.
- You must always check string, wave and data folder handles to make sure they are not null before using them.
- You must not dispose string handles passed from Igor via your runtime parameter structure. You also must not access such handles after your ExecuteOperation returns. If you want to keep the string data for later use, make a copy using **WMHandToHand** or **GetCStringFromHandle**.
- String handles are not C strings. Use **WMGetHandleSize** to determine the number of characters in the string. Use the **GetCStringFromHandle** XOPSupport routine to move the characters into a C string. See **Understand the Difference Between a String in a Handle and a C String** on page 221 for further discussion.
- You must never dispose or directly modify a wave handle. Wave handles belong to Igor.
- You must never dispose or directly modify a data folder handle. Data folder handles belong to Igor.
- If you are updating a file loader XOP that calls **SetFileLoaderOutputVariables**, you need to change it to call **SetFileLoaderOperationOutputVariables** instead. You also need to specify that your operation sets V_flag, S_fileName, S_path and S_waveNames when you call RegisterOperation.

For other debugging ideas, see Chapter 14.

Adding Functions

Overview

An XOP can add any number of external functions to Igor Pro.

An external function takes zero or more numeric, string, wave reference, data folder reference and structure parameters and returns a numeric, string, wave reference or data folder reference result. An external function is similar to a user-defined function except that the external function is implemented by C or C++ code in an XOP whereas the user-defined function is implemented by Igor code in Igor’s procedure window.

There are two reasons for creating external functions rather than user-defined functions. First, in many cases they run significantly faster than user-defined functions. Second, you can do things, like sample an I/O port, from an external function that you can’t do from a user-defined function.

Whereas an external operation has a variable number of parameters, an external function has a fixed number of parameters. Igor parses these parameters automatically and then passes them to the external function in a structure. Unlike user-defined functions, external functions can not have optional parameters.

External functions can be called anywhere Igor can call a built-in function, including from a user-defined function, from a macro, from the command line, or in a curve-fitting operation.

External functions can be thread-safe.

To add a function to Igor, you must create an XOPF resource to specify the name of the function, the number and type of its parameters, and the type of its result. Then you need to write the code that implements the function. The implementation accesses the parameters through the structure that Igor passes to it. It returns two kinds of results. One is the function result, returned to the calling user-defined function. The other is an error code, which Igor uses to determine when a fatal error has occurred.

External Function Examples

The XFUNC1 sample XOP, shipped with the XOP Toolkit, is a very simple XOP that adds three trivial external functions to Igor. The functions are XFUNC1Add(p1, p2), XFUNC1Div(p1, p2) and XFUNC1ComplexConjugate(p1). You can use this as a starting point for your external function XOP.

The XFUNC2 sample XOP implements two non-trivial external functions: logfit and plgndr.

logfit(wave, x) takes a single or double-precision wave containing three coefficients, a, b, and c, and an X value and returns a + b*log(c*x). This function is suitable for use in curve fitting. Its use is illustrated by the XFUNC2 Demo.pxp example experiment shipped in the XFUNC2 folder.

plgndr(l, m, x) takes three numbers and returns the value of the Legendre polynomial at x. The use of plgndr is also illustrated in the XFUNC2 Demo.pxp experiment. The Legendre polynomial and its parameters, l and m, are described in *Numerical Recipes in C*.

The XFUNC3 sample XOP implements two trivial external string functions, xstrcat0(str1, str2) and xstrcat1(str1, str2). Both simply return the concatenation of string expressions str1 and str2. The XFUNC3 Demo.pxp experiment contains tests that measure the speed of these functions.

The SimpleFit sample XOP illustrates implements a curve-fitting function and the **Guided Tour** on page 19 shows how to modify it to fit a different function.

Adding an External Function to Igor

When Igor Pro starts up, it examines each XOP file in the Igor Extensions folder or in its subfolders. It looks for an XOPF 1100 resource. This resource, if it exists, defines the functions that the XOP adds to Igor.

If the XOP has an XOPF 1100 resource, Igor loads the XOP into memory at Igor's startup time. It calls the XOP's XOPMain function, telling the XOP to initialize itself. The XOP stays in memory from launch time until Igor quits.

The XOPF 1100 Resource

For each external function added by an XOP, Igor needs to know the name of the function, the type of the function's return value and the number and type of parameters that the function expects. These things are defined in the XOPF 1100 resource which is defined in the XOP's .r file (*Macintosh*) or .rc file (*Windows*). For example, here is the XOPF resource for XFUNC1:

```
resource 'XOPF' (1100) {          // Macintosh, in XFUNC1.r.
   {
      "XFUNC1Add",                // Function name
      F_UTIL | F_EXTERNAL,        // Function category
      NT_FP64,                    // Return type is double precision
      {
         NT_FP64,                 // Parameter types
         NT_FP64,
      },

      "XFUNC1Div",                // Function name
      F_UTIL | F_EXTERNAL,        // Function category
      NT_FP64,                    // Return type is double precision
      {
         NT_FP64,                 // Parameter types
         NT_FP64,
      },

      "XFUNC1ComplexConjugate",   // Function name
      F_CMPLX | F_EXTERNAL,       // Function category
      NT_FP64 | NT_CMPLX,         // Return type is double complex
      {
         NT_FP64 | NT_CMPLX,      // Double complex parameter
      },
   }
};

1100 XOPF                         // Windows, in XFUNC1WinCustom.rc.
BEGIN
   "XFUNC1Add\0",                 // Function name
   F_UTIL | F_EXTERNAL,           // Function category
   NT_FP64,                       // Return type is double precision
      NT_FP64,                    // Parameter types
      NT_FP64,
      0,                          // 0 terminates list of parameter types.
   "XFUNC1Div\0",                 // Function name
   F_UTIL | F_EXTERNAL,           // Function category
   NT_FP64,                       // Return type is double precision
      NT_FP64,                    // Parameter types
      NT_FP64,
      0,            // 0 terminates list of parameter types.

   "XFUNC1ComplexConjugate\0",    // Function name
   F_CMPLX | F_EXTERNAL,          // Function category
   NT_FP64 | NT_CMPLX,            // Return type is double complex
      NT_FP64 | NT_CMPLX,         // Double complex parameter
      0,            // 0 terminates list of parameter types.

   0,               // 0 terminates the resource.
END
```

Here are the symbols available to specify the type of the external function's parameters and its return value.

Symbol	Decimal	Where Used	Description
NT_FP64	4	Return type, parameter type.	Double-precision floating point.
NT_FP64 | NT_CMPLX	5	Return type, parameter type.	Complex.
HSTRING_TYPE	8192	Return type, parameter type.	String handle.
WAVE_TYPE	16384	Return type, parameter type.	Wave handle.
DATAFOLDER_TYPE	256	Return type, parameter type.	Data folder handle.
FV_REF_TYPE	4096	Parameter type only.	Indicates pass-by-reference parameter.
FV_STRUCT_TYPE	1024	Parameter type only.	Structure. Always use with FV_REF_TYPE.

Note that other Igor number types, such as NT_FP32, NT_I32 and NT_I64, are not allowed.

If a parameter is a wave, the XOPF resource does not specify what kind of wave it is (floating point numeric, integer numeric, text). Igor will allow the user to pass any kind of wave to your external function so you must check the wave type at run time. See the logfit routine in XFUNC2Routines.cpp for an example.

There is one case in which you do need to use a numeric type in conjunction with a wave type - when you are creating a curve fitting function. You must specify the first parameter type as WAVE_TYPE | NT_FP64. This is explained under **Parameter and Result Types** on page 102.

The FV_REF_TYPE flag is used in conjunction with one of the other parameter types to signify that a parameter is passed by reference. It can be used with numeric and string parameters, and, with Igor Pro 8.00 or later, with wave and data folder reference parameters. Pass-by-reference is described under **Pass-By-Reference Parameters** on page 112.

FV_STRUCT_TYPE, which declares a structure parameter, must always be ORed with FV_REF_TYPE. Structure parameters are passed as pointers to structures.

Function Categories

The function category specifier is some combination of the symbols shown in the following table. The function category controls when the function will appear in Igor's Help Browser. For example, specifying the function's category as F_EXTERNAL | F_SPEC would make the function appear when All, External or Special are selected in the Functions popup menu in the Command Help tab of the browser.

Symbol	Bit Value	Function Help Dialog Category
F_TRIG	1	Trig
F_EXP	2	Exponential
F_SPEC	4	Special
F_CMPLX	8	Complex
F_TIMEDATE	16	Time and Date
F_ROUND	32	Rounding
F_CONV	64	Conversion
F_WAVE	128	About Waves
F_UTIL	256	Programming & Utility
F_NUMB	512	Numbers
F_ANLYZWAVES	1024	Wave Analysis
F_IO	2048	I/O
F_WINDOWS	4096	Windows
F_EXTERNAL	8192	External
F_THREADSAFE	16384	Thread-safe
F_STR	32768	String

You must always set the F_EXTERNAL bit for all external functions.

If your XOP is thread-safe, you must set the F_THREADSAFE bit.

Choose a Distinctive Function Name

NOTE: The name of an external function must not conflict with the names of present or future built-in operations or functions or with the names of present or future external operations or functions. *Don't use a vague or general name.* If you choose a name that clearly describes the function's purpose, chances are that it will not conflict.

The name that you choose for your function becomes unavailable for use as a wave name, window name or global variable name. For example, if you name your function Test then you can not use the name Test for any Igor object. If you have existing experiments that use Test, they will be in conflict with your function. Therefore, *pick a name that is unlikely to be useful for any other purpose.* This is especially important if you plan to share your XOP with other Igor users since they are probably not prepared to deal with errors when they open existing experiments.

Invoking an External Function

You can invoke an external function from Igor's command line, from a macro or from a user-defined function just as you would invoke a user-defined function. For example, the XFUNC1Div function, defined by the XOPF 1100 resource of the XFUNC1 XOP, can be invoked from Igor's command line using the following commands:

```
XFUNC1Div(3,4)
Print XFUNC1Div(3,4)
```

```
K0 = XFUNC1Div(K1, K2)
wave0 = XFUNC1Div(wave1, wave2)
```

The last example is a wave assignment statement. You may think that the waves wave1 and wave2 are passed to the XFUNC1Div function. This is not the case. Instead, Igor calls XFUNC1Div one time for each point in wave0, passing a single value from wave1 and another single value from wave2 each time. This is because the parameter types for XFUNC1Div are NT_FP64. If the parameter types were WAVE_TYPE, Igor would pass waves as illustrated by the logfit function in XFUNC2.

External Function Parameters and Results

The XFUNC1Div routine in XFUNC1.cpp illustrates how you access the function's parameters and how you return the result:

```
#pragma pack(2)       // All Igor structures are two-byte-aligned.
struct XFUNC1DivParams  {
   double p2;         // p2 is the second parameter to XFUNC1Div.
   double p1;         // p1 is the first parameter to XFUNC1Div.
   double result;
};
typedef struct XFUNC1DivParams XFUNC1DivParams;
#pragma pack()        // Reset structure alignment.

extern "C" int
XFUNC1Div(XFUNC1DivParams* p) // p is a pointer passed from Igor to XFUNC.
{
   p->result = p->p1 / p->p2; // XFUNC result.

   return 0;                  // XFUNC error code
}
```

The pragma statements insure that Igor and the XOP agree on the alignment of the parameter structure. See **Structure Alignment** on page 193 for details.

The external function should be declared `extern "C"` if you are writing a C++ XOP and `static` if you are writing a C XOP. For example:

```
extern "C" int        // C++
XFUNC1Div(XFUNC1DivParams* p)

static int            // C
XFUNC1Div(XFUNC1DivParams* p)
```

`extern "C"` is required in C++ code because all calls between Igor and the XOP use C calling conventions. Although it is not technically correct, using `static` in a C++ XOP also works with all of the C++ compilers that we have seen.

External Function Parameters

The parameter passed from Igor to XFUNC1Div is p. p is a pointer to a structure. The structure contains the parameters that the external function is to operate on. Parameters are passed by Igor to the external function in reverse order. The first element in the structure is the last parameter to the XFUNC1Div function. The last element in the structure is where the external function stores its result. This result field is the value that Igor returns to the calling function.

Here is the correspondence between parameter types and field data types:

Parameter Type	XOPF Symbol	Field Type	Notes
Number	NT_FP64	double	
Complex number	NT_FP64 | NT_CMPLX	double[2]	
String	HSTRING_TYPE	Handle	Always test for null string handles.
Wave	WAVE_TYPE	waveHndl	Always test for null wave handles.
DFREF	DATAFOLDER_TYPE	DataFolderHandle	Always test for null data folder handles.
Structure	FV_STRUCT_TYPE | FV_REF_TYPE	Pointer to structure	Always test for null structure pointers.

In the example above, the parameters are passed by value. Numeric and string parameters, and with Igor Pro 8.00 or later wave and data folder reference parameters, can also be passed by reference, as described under **Pass-By-Reference Parameters** on page 112. In that case, the structure fields would be defined as double* or Handle* and the parameter specification in the XOPF resource would be ORed with FV_REF_TYPE.

Igor can pass NULL for string, wave and DFREF handle parameters as well as structure pointer parameters. This happens when there is a bug in the calling user-defined function. Therefore you must always test theses types of parameters and return an error if they are NULL.

External Function Result and Error Code

In the XFUNC1Div example above, the function result, which is returned to the calling user-defined function, is set by this line:

```
   p->result = p->p1 / p->p2; // XFUNC result.
```

The error code, returned to Igor as the C function result, is set by this line:

```
   return 0;                  // XFUNC error code
```

The error code is zero if no error occurred or a built-in Igor error code (defined in IgorErrors.h) or an XOP-defined error code (defined in the XOP's .h file with corresponding error strings in the STR# 1100 resource - see **XOP Errors** on page 59 for details).

In the case of XFUNC1Div, there is nothing to go wrong so the error code is always zero. If you return a non-zero error code, Igor will abort procedure execution and display a dialog indicating the nature of the error. You should do this only in the case of fatal errors.

Parameter and Result Types

The XFUNC2 XOP adds an external function, logfit, that takes a wave and a numeric value as its parameters and returns a numeric value. The XOPF 1100 resource for this XOP looks like this:

```
resource 'XOPF' (1100) {          // Macintosh, in XFUNC2.r.
   {
      // y = a + b*log(c*x)
      "logfit",                   // Function name
      F_EXP | F_EXTERNAL,         // Function category
      NT_FP64,                    // Return value type
      {
         WAVE_TYPE | NT_FP64,     // Wave
         NT_FP64,                 // Double-precision x
      },

      . . .       // Other function definitions here.
   }
}

1100 XOPF                         // Windows, in XFUNC2WinCustom.rc.
BEGIN
   // y = a + b*log(c*x)
   "logfit\0",                    // Function name
   F_EXP | F_EXTERNAL,            // Function category
   NT_FP64,                       // Return value type
      WAVE_TYPE | NT_FP64,        // Wave
      NT_FP64,                    // Double precision x
      0,         // 0 terminates list of parameter types.

   . . .         // Other function definitions here.

   0,            // NOTE: 0 required to terminate the resource.
END
```

This says that the logfit function returns a double-precision number (NT_FP64). WAVE_TYPE | NT_FP64 indicates that the first parameter to logfit is a wave; as explained below, the NT_FP64 part is needed only to qualify this function as a curve-fitting function. The second parameter is a double-precision number.

The logfit function is written to handle single-precision or double-precision wave parameters. It checks the type of the wave parameter and returns an error if the type is not one of these.

Wave Parameters

The XOPF resource of the XFUNC2 XOP declares the wave parameter like this:

```
   WAVE_TYPE | NT_FP64,        // Wave
```

Normally, you can use just WAVE_TYPE for wave function parameters. However, if the function is a curve-fitting function, as in this example, you must use WAVE_TYPE | NT_FP64. The use of NT_FP64 here is needed to satisfy the CurveFit and FuncFit operations but it does not mean that Igor will pass only double-precision waves to the function. You must still check the wave type in the function.

NOTE: Igor can pass a NULL wave handle to your function. This happens during the execution of a user-defined function if the caller passes an uninitialized wave reference or a wave reference whose initialization failed.

Your function must check for a null wave handle as shown in this example from the logfit function in XFUNC2:

```
   // Check that wave handle is valid
   if (p->waveHandle == NULL) {
      SetNaN64(&p->result);          // Return NaN if wave is not valid
      return NULL_WAVE_OP;           // Return error to Igor
   }
```

NULL_WAVE_OP is an Igor error coded defined in IgorErrors.h.

You must also check that the wave's type is a type that you are prepared to handle. For example:

```
   // Check that wave is double-precision floating point
   int waveType = WaveType(p->waveHandle);
   if (waveType != NT_FP64) {
      SetNaN64(&p->result);          // Return NaN if wave is not valid
      return NT_FNOT_AVAIL;          // Return error to Igor
   }
```

NT_FNOT_AVAIL is an Igor error coded defined in IgorErrors.h.

Wave Results

To define an external function that returns a wave reference, specify WAVE_TYPE as the result type in the XOPF resource.

Here is code that shows how to return a wave reference. Given the name of a wave in the current data folder, it returns a wave reference or NULL if no such wave exists.

```
#pragma pack(2)      // All Igor structures are two-byte-aligned.
struct NameToWaveParams {
   Handle nameH;     // Name of wave in the current data folder.
   waveHndl result;
};
typedef struct NameToWaveParams NameToWaveParams;
#pragma pack()       // Reset structure alignment.

extern "C" int
NameToWave(NameToWaveParams* p)
{
   Handle nameH;
   waveHndl waveH;
   char name[MAX_OBJ_NAME+1];
   int result;

   result = 0;
   p->result = NULL;

   nameH = p->nameH;
   if (nameH == NULL)
      return USING_NULL_STRVAR;
   if (result = GetCStringFromHandle(nameH, name, sizeof(name)-1))
      return result;

   waveH = FetchWave(name);   // NULL if the wave does not exist
   p->result = waveH;

   return result;             // Error code returned to Igor
}
```

Data Folder Reference Parameters

A data folder reference parameter is represented by DATAFOLDER_TYPE in the XOPF resource.

NOTE: Igor can pass a NULL data folder handle to your function. This happens during the execution of a user-defined function if the caller passes an uninitialized data folder reference or a data folder reference whose initialization failed.

Your function must check for a null data folder handle as illustrated under **Data Folder Reference Example** on page 105.

Data Folder Reference Results

To define an external function that returns a data folder referenc, specify DATAFOLDER_TYPE as the result type in the XOPF resource.

Data Folder Reference Example

Here is code that shows how to take a data folder reference parameter and return a data folder reference as the function result. Given a data folder reference and an index, the GetChildDF function returns a data folder reference for a child data folder or NULL if the index is out-of-bounds.

```
// Macintosh XOPF resource, in .r file.
resource 'XOPF' (1100) {
   {
      "GetChildDF",              // Function name
      F_UTIL | F_EXTERNAL,       // Function category
      DATAFOLDER_TYPE,           // Return value type = Data folder reference
      {
         DATAFOLDER_TYPE,        // Parameter 0: Data folder reference
         NT_FP64,                // Parameter 1: Numeric index
      },
   }
};

// Windows XOPF resource, in WinCustom.rc file.
1100 XOPF
BEGIN
   "GetChildDF\0",               // Function name
   F_UTIL | F_EXTERNAL,          // Function category
   DATAFOLDER_TYPE,              // Return value type = Data folder reference
      DATAFOLDER_TYPE,           // Parameter 0: Data folder reference
      NT_FP64,                   // Parameter 1: Numeric index
      0,             // 0 terminates list of parameter types.
   0,                // 0 terminates the resource.
END

// C++ code in .cpp file.

#pragma pack(2)      // All Igor structures are two-byte-aligned.
struct GetChildDFParams {
   double index;              // Index to child data folder
   DataFolderHandle dfr;      // Parent data folder
   DataFolderHandle result;
};
typedef struct GetChildDFParams GetChildDFParams;
#pragma pack()       // Reset structure alignment.

extern "C" int
GetChildDF(GetChildDFParams* p)
{
   DataFolderHandle parentDFH;
   DataFolderHandle childDFH;
   int index;
   int result;

   result = 0;
   p->result = NULL;

   parentDFH = p->dfr;
   if (parentDFH == NULL)
      return NULL_DATAFOLDER_OP;
   index = p->index;

   result = GetIndexedChildDataFolder(parentDFH, index, &childDFH);
   p->result = childDFH;
   return result;       // Error code returned to Igor
}
```

NULL_DATAFOLDER_OP is an Igor error coded defined in IgorErrors.h.

Complex Parameters and Results

XFUNC1 adds a function that returns the complex conjugate of a complex parameter. The XOPF 1100 resource for a complex function looks like this:

```
// Macintosh, in XFUNC1.r.
resource 'XOPF' (1100) {
   {
      "XFUNC1ComplexConjugate",  // Function name
      F_CMPLX | F_EXTERNAL,      // Function category
      NT_FP64 | NT_CMPLX,        // Return value type = DPC
      {
         NT_FP64 | NT_CMPLX,     // Double-precision complex parameter
      },
   }
};

// Windows, in XFUNC1WinCustom.rc.
1100 XOPF
BEGIN
   "XFUNC1ComplexConjugate\0",   // Function name
   F_CMPLX | F_EXTERNAL,         // Function category
   NT_FP64 | NT_CMPLX,           // Return value type = DPC
      NT_FP64 | NT_CMPLX,        // Double-precision complex parameter
      0,              // 0 terminates list of parameter types.
   0,                 // 0 terminates the resource.
END
```

The first use of NT_FP64 | NT_CMPLX specifies that the return value is double-precision, complex. The second use of NT_FP64 | NT_CMPLX specifies that the parameter is double-precision, complex.

See XFUNC1ComplexConjugate in XFUNC1.cpp for the code that implements a complex function.

Strings Parameters and Results

The XFUNC3 XOP adds an external function that takes two string parameters and returns a string result. The XOPF 1100 resource for this XOP looks like this:

```
// Macintosh, in XFUNC3.r.
resource 'XOPF' (1100) {
   {
      // str1 = xstrcat0(str2, str3)
      "xstrcat0",                // Function name
      F_STR | F_EXTERNAL,        // Function category (string)
      HSTRING_TYPE,              // Return value type is string handle.
      {
         HSTRING_TYPE,           // First parameter is string handle.
         HSTRING_TYPE,           // Second parameter is string handle.
      },

      // str1 = xstrcat1(str2, str3)
      "xstrcat1",                // Function name
      F_STR | F_EXTERNAL,        // Function category (string)
      HSTRING_TYPE,              // Return value type is string handle.
      {
         HSTRING_TYPE,            // First parameter is string handle.
         HSTRING_TYPE,            // Second parameter is string handle.
      },
   }
};

// Windows, in XFUNC3WinCustom.rc.
1100 XOPF
BEGIN
   // str1 = xstrcat0(str2, str3)
   "xstrcat0\0",                  // Function name
   F_STR | F_EXTERNAL,            // Function category (string)
      HSTRING_TYPE,               // Return value type is string handle.
      HSTRING_TYPE,               // First parameter is string handle.
      HSTRING_TYPE,               // Second parameter is string handle.
      0,            // 0 terminates list of parameter types.

   // str1 = xstrcat1(str2, str3)
   "xstrcat1\0",                  // Function name
   F_STR | F_EXTERNAL,            // Function category (string)
      HSTRING_TYPE,               // Return value type is string handle.
      HSTRING_TYPE,               // First parameter is string handle.
      HSTRING_TYPE,               // Second parameter is string handle.
      0,            // 0 terminates list of parameter types.

   0,               // 0 terminates the resource.
END
```

This resource defines two string functions that do exactly the same thing. The function declarations are identical except for the function name. The reason for having identical functions is to demonstrate two methods by which Igor can call an external function. These methods are explained under **FUNCTION Message Versus Direct Methods** on page 116.

The return value type of HSTRING_TYPE says that the function returns a string. The HSTRING_TYPEs indicate both parameters are strings.

This function is invoked as follows:

```
String aString
aString = xstrcat0("Hello", " out there")
```

Both the xstrcat0 and xstrcat1 external functions wind up calling the xstrcat function in XFUNC3.cpp. xstrcat is defined as follows:

```
#pragma pack(2)      // All Igor structures are two-byte-aligned.
struct xstrcatParams {
      Handle str3;
      Handle str2;
      Handle result;
};
typedef struct xstrcatParams xstrcatParams;
#pragma pack()       // Reset structure alignment.

extern "C" int
xstrcat(xstrcatParams* p)
{
   Handle str1;                   // output handle
   int len2, len3;
   int err=0;

   p->result = NULL;              // Must be set to a valid handle or NULL
   str1 = NULL;                    // If error occurs, result is NULL.
   if (p->str2 == NULL) {          // Error -- input string does not exist.
      err = NO_INPUT_STRING;
      goto done;
   }
   if (p->str3 == NULL) {          // Error -- input string does not exist.
      err = NO_INPUT_STRING;
      goto done;
   }

   len2 = WMGetHandleSize(p->str2);    // length of string 2
   len3 = WMGetHandleSize(p->str3);    // length of string 3
   str1 = WMNewHandle(len2 + len3);    // Get output handle.
   if (str1 == NULL) {
      err = NOMEM;
      goto done;                       // out of memory
   }

   memcpy(*str1, *p->str2, len2);
   memcpy(*str1+len2, *p->str3, len3);

done:
   WMDisposeHandle(p->str2);       // Get rid of input parameters. (OK if NULL)
   WMDisposeHandle(p->str3);       // Get rid of input parameters. (OK if NULL)
   p->result = str1;               // Must be a valid handle or NULL

   return err;
}
```

The error code NO_INPUT_STRING is defined by the XOP whereas NOMEM is a standard Igor error code defined in IgorErrors.h. You could also use the Igor USING_NULL_STRVAR error code in place of NO_INPUT_STRING.

Strings in Igor are stored in plain Macintosh-style handles, even when running on Windows. The handle contains the string's text, with neither a count byte nor a trailing null byte. Use **WMGetHandleSize** to find the number of characters in the string. To use C string functions on this text you need to copy it to a local buffer and null-terminate it (using **GetCStringFromHandle**) or add a null terminator to the handle. If you pass the handle back to Igor, you must remove the null terminator. See **Understand the Difference Between a String in a Handle and a C String** on page 221 for further discussion of string handles.

An external string function returns a handle as its result. It can return NULL in the event of an error.

NOTE: Before your function returns, you must store a valid handle in the result field or set it to NULL.

NOTE: String parameter handles passed by Igor to an external function belong to the XOP. The XOP must dispose or reuse the handle.

Unlike a wave handle, a handle passed as a string parameter to an external function belongs to that function. The external function must dispose of the handle. Alternately, the external function can return the handle as the function result after possibly modifying its contents.

NOTE: As for wave handles, it is possible for a string parameter to be passed as NULL because the string does not exist during the execution of a compiled user-defined function. The external function must check for this.

xstrcat checks its parameters. If either is NULL, it returns NULL as a result. Otherwise, it creates a new handle and concatenates its input parameters into the new handle. This new handle is stored as the result and the input handles are disposed. The result handle belongs to Igor. The external function must not dispose of it or access it in any way once it returns to Igor.

Structure Parameters

Structure parameters are passed as pointers to structures. These pointers always belong to Igor. You must never dispose or resize a memory block using a structure pointer but you may read and write its fields.

An instance of an Igor structure can be created only in a user-defined function and exists only while that function is running. Therefore, external functions that have structure parameters can be called only from user-defined functions, not from the command line or from macros.

The pointer for a structure parameter can be NULL. This would happen if the user supplies * as the parameter or in the event of an internal error in Igor. Therefore you must always test a structure parameter to make sure it is non-NULL before using it.

If you receive a NULL structure pointer as a parameter and the structure is required for the operation, return an EXPECTED_STRUCT error code. Otherwise, interpret this to mean that the user wants default behavior.

Unlike the case of external operations, the Igor compiler has no way to know what type of structure your external function expects. Therefore, Igor will allow any type of structure to be passed to an external function. When writing Igor procedures that call the external function, you must be careful to pass the right kind of structure.

You must make sure that the definition of the structure in Igor matches the definition in the XOP. Otherwise a crash is likely to occur.

Here is the XOPF resource declaration for an external function that takes one parameter which is a pointer to a structure:

```
// Macintosh
resource 'XOPF' (1100) {
   {
      // result = XtestF1Struct(struct F1Struct* s)
      "XTestF1Struct",        // Function name
      F_EXTERNAL,             // Function category
      NT_FP64,                // Return value type
      {
         FV_STRUCT_TYPE | FV_REF_TYPE, // Pointer to F1Struct.
      },
   }
};

// Windows
1100 XOPF
BEGIN
   // result = XTestF1Struct(struct F1Struct* s)
   "XTestF1Struct\0",         // Function name
   F_EXTERNAL,                // Function category
   NT_FP64,                   // Return value type
      FV_STRUCT_TYPE | FV_REF_TYPE,    // Pointer to F1Struct
      0,             // 0 terminates parameters.

   0,                // 0 terminates functions.
END
```

The use of FV_STRUCT_TYPE | FV_REF_TYPE says that the function takes a pointer to a structure as a parameter.

External Function Structure Parameter Example

Here is Igor procedure code which invokes this external function.

```
Constant kF1StructVersion = 1000 // 1000 means 1.000
```

```
Structure F1Struct               // Structure of parameter to XTestF1Struct.
   uint32 version                // Structure version.
   double num
   String strH
   Wave waveH
   double out
EndStructure

Function Test()
   STRUCT F1Struct s

   s.version = kF1StructVersion
   s.num = 4321
   s.strH = "This is a test."
   Wave s.waveH = jack
   s.out = 0

   Variable result = XTestF1Struct(s)
End
```

Here is C code that implements the external function:

```
#pragma pack(2)      // All Igor structures are two-byte-aligned.

#define kF1StructureVersion 1000    // 1000 means 1.000.

struct F1Struct {                   // Structure of parameter.
   UInt32 version;                  // Structure version.
   double num;
   Handle strH;
   waveHndl waveH;
   double out;
};
typedef struct F1Struct F1Struct;

struct F1Param {                    // Parameter structure.
   F1Struct* sp;                    // This param is pointer to struct.
   double result;
};
typedef struct F1Param F1Param;

#pragma pack()       // Reset structure alignment.

int
XTestF1Struct(struct F1Param* p)
{
   struct F1Struct* sp;
   char buffer[256];
   char str[128];
   char nameOfWave[MAX_OBJ_NAME+1];
   int err=0;

   sp = p->sp;
   if (sp == NULL)  {
      err = EXPECT_STRUCT;
      goto done;
   }

   if (sp->version != kF1StructureVersion ) {
      err = INCOMPATIBLE_STRUCT_VERSION;
      goto done;
   }

   sp->out = 1234;

   if (sp->strH == NULL) {
      err = USING_NULL_STRVAR;       // Error: input string does not exist
      goto done;
   }

   if (sp->waveH == NULL) {
      err = NULL_WAVE_OP;            // Error: expected wave
      goto done;
   }

   if (err = GetCStringFromHandle(sp->strH, str, sizeof(str)-1))
      goto done;                     // String too long.

   WaveName(sp->waveH, nameOfWave);

   sprintf(buffer, "num=%g, str=\"%s\", wave='%s'" CR_STR,
                                 sp->num, sp->str, nameOfWave);
   XOPNotice(buffer);

done:
   p->result = err;
   return err;
}
```

There are two structures involved in this example: the F1Param structure and the F1Struct structure. F1Param defines the format of the *parameter structure* – the structure through which Igor passes any and all parameters to the external function. F1Struct defines the format of the one *structure parameter* passed to this function. p is a pointer to a parameter structure. sp is a pointer to a particular parameter which is a pointer to an Igor structure whose format is defined by F1Struct.

The Igor procedure code must declare an F1Struct structure and the C code must declare a matching C structure. The use of the version field is a convention for preventing a crash if the procedure version of the structure and the C version get out-of-sync.

The Igor code declares the F1Struct structure. It then creates and initializes an instance of it, named s. It then passes s (actually a pointer to s) to the XTestF1Struct external function.

The XTestF1Struct external function first checks that a valid pointer has been passed. It then checks that the version of the structure is compatible before accessing its fields. It can read, write or read and write any of the fields.

An advanced programmer may want to use a more flexible versioning scheme by allocating reserved fields in the structure and then using the version field to handle whatever version of the structure was passed from the Igor procedure. If possible you should simplify your life by using the simplified versioning technique shown above. However, if you decide to save structure data to disk and later read it back, you will have to deal with more complex versioning issues, as well as cross-platform byte-order issues. You will also have to deal with versioning issues if your XOP will be used by many people and you can not force them to update their Igor procedure code when you update your XOP.

The F1Struct structure contains a string handle field named strH. Unlike the case of a parameter string handle, the external operation does not receive ownership of a string handle in a structure parameter and must not dispose it.

For further important details see **Using Igor Structures as Parameters** on page 194.

Wave Handles In Structures

Usually a waveHndl field in a structure is used to pass a wave reference from Igor to your XOP. However, it can also be used to pass a wave reference from your XOP to Igor.

If you store a wave handle in a waveHndl field of a structure you need to inform Igor by calling **HoldWave** on the structure field. By doing this, you maintain the integrity of Igor's internal wave reference count. For details see **Wave Reference Counting** on page 131.

Data Folder Handles In Structures

Usually a DataFolderHandle field in a structure is used to pass a data folder reference from Igor to your XOP. However, it can also be used to pass a data folder reference from your XOP to Igor.

If you store a data folder handle in a DataFolderHandle field of a structure you need to inform Igor by calling **HoldDataFolder** on the structure field. By doing this, you maintain the integrity of Igor's internal data folder reference count. For details see **Data Folder Reference Counting** on page 143.

Pass-By-Reference Parameters

External functions can have pass-by-reference parameters. Numeric, string and structure parameters, and with Igor Pro 8.00 or later wave and data folder reference parameters, can be pass-by-reference.

Normally function parameters are pass-by-value. This means that the called function (the external function in this case) can not modify the value of the parameter as seen by the calling user-defined function.

With a pass-by-reference parameter, the called function *can* modify the parameter's value and the calling user-defined function will receive the modified value on return. Pass-by-reference provides a way for an external function to return multiple values to the calling function, in addition to the function result.

There are three differences in the implementation of a pass-by-reference parameter compared to a normal pass-by-value parameter.

First, in the XOPF resource, when declaring the parameter type, you use the FV_REF_TYPE flag. Here is an example of an XOPF that declares a function with three pass-by-reference parameters:

```
resource 'XOPF' (1100) {
   {
      // number = ExampleFunc(number,complexNumber,str)
      "ExampleFunc",             // Function name
      F_UTIL | F_EXTERNAL,       // Function category
      NT_FP64,                   // Return value type
      {                          // Parameter types
         NT_FP64 | FV_REF_TYPE,
         NT_FP64 | NT_CMPLX | FV_REF_TYPE,
         HSTRING_TYPE | FV_REF_TYPE,
      },
   }
};
```

Second, in the parameter structure passed to the XFUNC, the fields corresponding to pass-by-reference parameters must be pointers to doubles, pointers to Handles for string parameters, or with Igor Pro 8.00 or later, pointers to waveHndls or pointers to DataFolderHandles. For example:

```
#pragma pack(2)      // All Igor structures are two-byte-aligned.
struct ExampleParams {           // Fields are in reverse order.
   Handle* strHPtr;              // Parameter is pass-by-reference.
   double* complexNumberPtr;     // Parameter is pass-by-reference.
   double* scalarNumberPtr;      // Parameter is pass-by-reference.
   double result;                // Function result field.
};
```

```
typedef struct ExampleParams ExampleParams;
typedef ExampleParams* ExampleParamsPtr;
#pragma pack()       // Reset structure alignment.
```

The third difference has to do with string handles. As with pass-by-value, when your XFUNC receives a pass-by-reference string parameter, you own the handle pointed to by the Handle* field, strHPtr in this case. The difference is that you must also return a handle via this field and Igor owns the handle that you return. Often it is convenient to reuse the input handle as the output handle, as the example code below shows, in which case ownership of the handle passes from the XOP back to Igor and you must not dispose it. If you return a different handle then you must dispose the input handle.

On input, a string, wave reference, or data folder reference pass-by-reference parameter may point to a valid string, wave or data folder handle, or may point to NULL. You must test for NULL before using what these parameters point to as inputs.

This example shows how to access and modify pass-by-reference parameters:

```
int
ExampleFunc(ExampleParamsPtr p)
{
   char str[256];
   char buffer[512];
   int err;

   err = 0;

   // GetCStringFromHandle tolerates NULL handles.
   GetCStringFromHandle(*p->strHPtr, str, sizeof(str)-1);
   sprintf(buffer, "ExampleFunc received: %g, (%g,%g), %s" CR_STR,
      *p->scalarNumberPtr,
      p->complexNumberPtr[0], p->complexNumberPtr[1],
      str);
   XOPNotice(buffer);

   *p->scalarNumberPtr *= 2;
   p->complexNumberPtr[0] *= 2;
   p->complexNumberPtr[1] *= 2;

   // *p->strHPtr will be NULL if caller passes uninitialized string.
   if (*p->strHPtr == NULL)
      *p->strHPtr = WMNewHandle(0L);

   if (*p->strHPtr != NULL) {
      strcpy(str, "Output from ExampleFunc");
      err = PutCStringInHandle(str, *p->strHPtr);
   }

   /* Do not dispose *p->strHPtr. Since it is a pass-by-reference parameter,
      the calling function retains ownership of this handle.
   */

   p->result = 0;

   return err;
}
```

Pass-By-Reference Wave Reference Parameters

With Igor Pro 8.00 or later, you can define an external function that takes a pass-by-reference wave reference parameter. This section shows how to do that.

First, in the XOPF resource, you must declare the parameter as a pass-by-reference wave parameter:

```
resource 'XOPF' (1100) {
   {
      "DemoPassByReferenceWave",       // Function name
      F_UTIL | F_EXTERNAL,             // Function category
      NT_FP64,                         // Return value type
      {                                // Parameter types
         WAVE_TYPE | NT_FP64 | FV_REF_TYPE,
      },
   }
};
```

WAVE_TYPE identifies the parameter as a wave. FV_REF_TYPE identifies it as pass-by-reference.

Because Igor's compiler is relatively strict when compiling pass-by-reference parameters, the NT_FP64 flag is needed to tell Igor that the parameter is a *numeric* wave reference rather than a text wave, data folder reference wave, or wave reference wave. The Igor compiler allows the user to pass any numeric wave reference (e.g., WAVE, WAVE/D, WAVE/C) for this parameter - it is not restricted to 64-bit floating point waves.

If you wanted to define a function taking a pass-by-reference text reference wave (WAVE/T), you would use TEXT_TYPE instead of NT_FP64.

If you wanted to define a function taking a pass-by-reference data folder reference wave (WAVE/DF), you would use DATAFOLDER_TYPE instead of NT_FP64.

If you wanted to define a function taking a pass-by-reference wave reference wave (WAVE/WAVE), you would use WAVEWAVE_TYPE instead of NT_FP64. However this will not work. The value for WAVEWAVE_TYPE does not fit in 16 bits and so can not be used in the XOPF resource. This means it is not possible to declare an external function parameter as a pass-by-reference wave reference wave.

Passing a wave reference *by reference* transfers ownership of the wave. This requires the proper use of wave reference counting via HoldWave and ReleaseWave, as explained below. For background information, see **Wave Reference Counting** function on page 131.

In the usual case, a pass-by-reference wave reference parameter is used only to transfer a wave reference from a subroutine (your external function in this case) to the calling routine (an Igor user-defined function). In this case, it is an output from the subroutine. However, from the point of view of the subroutine, a pass-by-reference parameter can be an input, an output, or both.

When your external function is called, the pass-by-reference wave reference parameter may be NULL or it may contain a valid wave reference. Your external function may leave the original wave reference in place, store NULL in its place, or store a new wave reference in it.

With pass-by-reference wave reference parameters, the provider of the wave reference calls **HoldWave** and the recipient of the wave reference calls **ReleaseWave** when it is finished with the wave reference. When your external function is called, it is the recipient and calls ReleaseWave. When it returns, it is the provider and calls HoldWave.

The following code illustrates how to implement a pass-by-reference wave reference parameter.

```
#pragma pack(2)          // All structures passed to Igor are two-byte aligned
struct DemoPassByReferenceWaveParams {
   waveHndl* waveHPtr;  // Pass-by-reference wave reference
   double result;
};
typedef struct DemoPassByReferenceWaveParams DemoPassByReferenceWaveParams;
#pragma pack()           // Reset structure alignment to default.

extern "C" int
DemoPassByReferenceWave(DemoPassByReferenceWaveParams* p)
{
   waveHndl waveH = nullptr;
   int err = 0;

   p->result = 0;

   if (p->waveHPtr == nullptr)
      return GENERAL_BAD_VIBS;   // Should not happen

   waveH = *p->waveHPtr;
   if (waveH != nullptr) {
      // We received a wave as an input via the pass-by-reference parameter
      // ... Do something with the input wave if appropriate ...

      /* By virtue of pass-by-reference, we own waveH. We are now finished
         using it and so must release it. ReleaseWave does nothing if waveH
         is NULL. Otherwise it decrements the wave's reference count and sets
         waveH to NULL.
      */
      ReleaseWave(&waveH);    // Sets waveH to NULL
      *p->waveHPtr = nullptr; // Return NULL as output wave reference for now
   }

   // Make a free wave to return via the pass-by-reference parameter
   CountInt dimSizes[MAX_DIMENSIONS+1];
   MemClear(dimSizes, sizeof(dimSizes));
   dimSizes[0] = 3;                             // Three-row 1D wave
   DataFolderHandle dfH = (DataFolderHandle)-1; // Create free wave
   err = MDMakeWave(&waveH, "DemoPBROutputWave", dfH, dimSizes, NT_FP64, 1);
   if (err != 0)
      return err;

   /* We will be passing ownership of the wave to the calling routine
      so we increment its reference count.
   */
   HoldWave(waveH);

   /* This assignment transfers our ownership of the wave to the calling
      routine. The calling routine is responsible for calling ReleaseWave on
      the wave when it is finished with it.
   */
   *p->waveHPtr = waveH;      // Return output wave reference
   waveH = nullptr;           // We no longer have ownership of this wave

   return 0;
}
```

Here is an Igor user-defined function that calls DemoPassByReferenceWave:

```
Function Demo()
   Wave w = NewFreeWave(4, 2)    // 2-point free wave
   DemoPassByReferenceWave(w)    // Replace with 3-point free wave
   Print w
End
```

DemoPassByReference receives the 2-point free wave from the Demo function. It returns a 3-point free wave to the Demo function. If you change Demo to this:

```
Function Demo()
   Wave/Z w                      // NULL wave reference
   DemoPassByReferenceWave(w)    // Replace with 3-point single-precision wave
   Print w
End
```

then DemoPassByReference receives a NULL wave reference on input. It still returns a 3-point wave to the Demo function.

You can receive a non-free wave on input and you can return a non-free wave on output. The difference is that a non-free wave's reference count is incremented when it is installed in its data folder and decremented when it is killed.

Pass-By-Reference Data Folder Reference Parameters

With Igor Pro 8.00 or later, you can define an external function that takes a pass-by-reference data folder reference parameter.

In the XOPF resource, you must declare the parameter as a pass-by-reference data folder reference parameter:

```
resource 'XOPF' (1100) {
   {
      "DemoPassByReferenceWave",       // Function name
      F_UTIL | F_EXTERNAL,             // Function category
      NT_FP64,                         // Return value type
      {                                // Parameter types
         DATAFOLDER_TYPE | FV_REF_TYPE,
      },
   }
};
```

DATAFOLDER_TYPE identifies the parameter as a wave. FV_REF_TYPE identifies it as pass-by-reference.

The rest is analogous to pass-by-reference wave reference parameters except that you use **HoldDataFolder** and **ReleaseDataFolder** instead of HoldWave and ReleaseWave. See **Pass-By-Reference Wave Reference Parameters** on page 113.

Keep External Functions in Memory

All XOPs with external functions must remain resident all of the time. You can satisfy this by just not calling the SetXOPType(TRANSIENT) XOPSupport routine.

FUNCTION Message Versus Direct Methods

When an external function is invoked, Igor calls code in the XOP that defined the function. There are two methods for calling the code:

- The FUNCTION message method
- The direct-call method

The rationale for the FUNCTION message method no longer exists so the direct method is recommended for all modern external functions.

The FUNCTION message method of calling the external function uses the same techniques for communication between Igor and the XOP as all other XOP Toolkit messages. Igor calls your XOP's XOPEntry function, passing it the FUNCTION message. This message has two arguments. The first argument is an index number starting from zero that identifies which of your external functions is being invoked. For the XFUNC1 XOP, if the XFUNC1Add function is being invoked, the index is 0. If the XFUNC1Div function is being invoked, the index is 1. The second argument is a pointer to a structure containing the parameters to the function and a place to store the function result as described above.

The DoFunction routine in XFUNC1.cpp decides which of the external functions is being invoked. It then calls that function, passing it the necessary pointer. It acts as a dispatcher.

When calling a direct function, Igor does not send a FUNCTION message to your XOPEntry routine but instead calls your function code directly, passing to it a pointer to the structure containing the parameters and a place to store the function result.

Here is how Igor decides which method to use when calling an external function. When Igor starts up it examines each XOP's XOPF 1100 resource to see if it adds external functions. If the XOP does add functions, Igor loads the XOP into memory and sends it the INIT message (i.e., calls the XOP's XOPMain function). Then it sends the XOP the FUNCADDRS message once for each external function that the XOP adds. The FUNCADDRS message has one argument: the index number for an external function added by the XOP. If the XOP returns NULL in response to this message then Igor will call that external function using the FUNCTION message method. If the XOP returns other than NULL, this result is taken as the address of the routine in the XOP for Igor to call directly when the external function is invoked.

XFUNC3 illustrates both ways of registering a function. In response to the FUNCADDRESS message from Igor, it registers the xstrcat0 function as direct by returning an address, and registers the xstrcat1 function as message-based by returning NULL .

Thread-Safe External Functions

Igor supports thread-safe user-defined functions. This makes it possible to utilize more than one processor on a multi-processor computer.

Igor also supports thread-safe external functions with certain restrictions discussed below. This section tells you how to convert a normal external function to a thread-safe function using the SimpleFit XOP as an example.

Writing thread-safe code is trickier than writing regular code. For example, your function can not write to a global variable because two instances of your function might write different values to the global and interfere with each other's operation. Many web sites explain what "thread-safe" means and what you can and can not do in thread-safe code.

If you mark an external function as thread-safe, Igor allows that function to be called from user-defined functions marked as thread-safe. The user-defined function and your external function may then be called from Igor's main thread or from an Igor pre-emptive thread.

You can not call an XOPSupport routine when running in an Igor pre-emptive thread unless the routine is marked as thread-safe. The documentation for each XOPSupport routine states whether it is thread-safe or not.

You can call a thread-safe XOPSupport routine only from Igor's main thread or from an Igor pre-emptive thread, not from a private thread that you create on your own.

Changes for Thread-Safe External Functions

A few changes are needed to make an external function thread-safe. In this section we illustrate these changes using the logfit external function from XFUNC2 as an example.

Here are the steps for making an external function thread-safe:

1. Make sure that your function uses the direct-call method as described under **FUNCTION Message Versus Direct Methods** on page 116.
2. Add the F_THREADSAFE bit to the category field of your XOPF resource.

   In the XFUNC2.r and XFUNC2.rc, change the category from:

   ```
   F_EXP | F_EXTERNAL,
   ```

   to

```
      F_EXP | F_THREADSAFE | F_EXTERNAL,
```

3. Add a "tp" field to your external function's parameter structure. The tp field is a pointer to private Igor thread-related data that is not currently used but may be used in the future. It may be NULL. The tp field must be added just before the result field, like this:

   ```
   typedef struct FitParams {
      double x;
      waveHndl waveHandle;
      UserFunctionThreadInfoPtr tp; // Pointer to Igor private data.
      double result;
   } FitParams, *FitParamsPtr;
   ```

4. Check to make sure that your thread-safe external function does not do anything that is not thread-safe.

More on Multithreading

For additional discussion of multithreading in XOPs see **Multithreading** on page 159.

Error Checking and Reporting

The logfit function in XFUNC2 illustrates error checking and reporting. The function is designed for use as a curve-fitting function but it also can be invoked from an Igor procedure as follows:

```
K0 = logfit(wave0, x);
```

The value that will be stored in K0 is returned via the result field of the structure that Igor passes to the logfit function. In addition to this result, the function has a C function result which Igor looks at to see if the function encountered a fatal error.

logfit is defined as follows:

```
#pragma pack(2)      // All Igor structures are two-byte-aligned.
struct LogFitParams {
   double x;                  // Independent variable.
   waveHndl waveHandle;       // Coefficient wave (contains a, b, c coefs).
   double result;
};
typedef struct LogFitParams LogFitParams;
typedef struct LogFitParams *LogFitParamsPtr;
#pragma pack()       // Reset structure alignment.

int
logfit(LogFitParamsPtr p)     // y = a + b*log(c*x)
{
   double* dPtr;              // Pointer to double-precision wave data
   float* fPtr;               // Pointer to single-precision wave data
   double a, b, c;

   // Check that wave handle is valid
   if (p->waveHandle == NULL) {
      SetNaN64(&p->result);   // Return NaN if wave not valid.
      return NULL_WAVE_OP;
   }

   // Check coefficient wave’s numeric type.
   switch (WaveType(p->waveHandle)) {
      case NT_FP32:
         fPtr = (float*)WaveData(p->waveHandle);
         a = fPtr[0];
         b = fPtr[1];
         c = fPtr[2];
```

```
         break;
      case NT_FP64:
         dPtr = (double*)WaveData(p->waveHandle);
         a = dPtr[0];
         b = dPtr[1];
         c = dPtr[2];
         break;
      default:                   // Can't handle this data type.
         p->result = nan(255);   // Return NaN.
         return REQUIRES_SP_OR_DP_WAVE;
   }

   p->result = a + b*log10(c*p->x);

   return 0;
}
```

The LogFitParams structure is defined in XFUNC2.h.

The NULL_WAVE_OP error code is defined in IgorErrors.h. The REQUIRES_SP_OR_DP_WAVE error code is defined in XFUNC2.h with a corresponding string in XFUNC2's STR# 1100 resource.

Notice that logfit starts off by making sure that the wave parameter is not NULL. This is necessary because the external function can be called from an Igor user-defined function. User-defined functions are compiled by Igor and can refer to a wave that doesn't exist at compile time. If, when the compiled function is executed, the wave still does not exist, it will be passed to logfit as a NULL handle.

When Igor passes a wave to an external function, *it does not do type conversion*. The wave passed to logfit could be single precision, double precision or integer. It could also be complex. It could even be a text wave, a wave reference wave or a data folder reference wave. Logfit returns NaN if the wave passed to it is other than single- or double-precision real.

Returning a non-zero value as the C function result from an external function causes Igor to abort procedure execution and display an error alert. Therefore, you should do this only if the error is fatal - that is, if it is likely to make any further processing meaningless. If we did not want passing the wrong type of wave to logfit to be a fatal error, we would set `p->result` to NaN, as shown above, and then return zero to Igor, instead of NULL_WAVE_OP or REQUIRES_SP_OR_DP_WAVE.

Accessing Igor Data

Overview

This chapter explains how to access Igor data – waves, numeric variables, string variables and the data folders that contain them.

Dealing with waves, string variables, and data folders involves the use of Macintosh-style handles, whether your XOP is running on Macintosh or Windows. You need to understand Macintosh-style handles in order to access and manipulate Igor data. See **WM Memory XOPSupport Routines** on page 179 for details.

Waves

A wave is stored in a block of memory in the heap, referenced by a handle. The first hundred or so bytes of the block contains a structure that describes the wave. After that comes the main wave data followed by optional wave data such as the wave note. You will often need to get a wave handle from Igor or pass a wave handle to Igor to identify a particular wave to operate on.

You never need to and never should attempt to deal with the wave structure directly.

Instead, use the XOPSupport routines, provided in XOPWaveAccess.c and listed in Chapter 15, to get and set wave data and properties.

You also must not treat a wave handle as a WM memory handle by passing it to normal handle routines such as WMGetHandleSize or as a Macintosh native handle by passing it to a Macintosh native routine such as GetHandleSize.

Instead, use the XOPSupport routines, provided in XOPWaveAccess.c and listed in Chapter 15.

Routines for Accessing Waves

The XOPSupport routines for dealing with waves are described in detail under **Routines for Accessing Waves** on page 240. Here is a summary of the commonly-used routines.

Getting a Handle to a Wave

Routine	Description
MakeWave	Makes 1D waves.
MDMakeWave	Makes waves of dimension 1 through 4.
FetchWave	Returns a handle to a wave in the current data folder given its name.
GetDataFolderObject	Returns a handle to a wave given its name and data folder.

In addition, you can create external operations and external functions that receive wave handles from Igor as parameters.

Getting Wave Properties

Routine	Description
WaveName	Returns wave name given a handle.
WaveType	Returns data type.
WavePoints	Returns number of elements in all dimensions.
MDGetWaveDimensions	Returns number of elements in each dimension.
WaveScaling	Gets scaling for the row dimension only.
MDGetWaveScaling	Gets scaling for the specified dimension.
WaveUnits	Gets row dimension units, data units.
MDGetWaveUnits	Gets units for the specified dimension or data units.
MDGetDimensionLabel	Gets dimension label for specified dimension index.
GetWaveDimensionLabels	Gets all dimension labels for entire wave.
WaveNoteCopy	Gets the wave note.
WaveLock	Returns the lock state of the wave.

Setting Wave Properties

Routine	Description
SetWaveScaling	Sets scaling for the row dimension only.
MDSetWaveScaling	Sets wave scaling for the specified dimension.
SetWaveUnits	Sets row dimension units, data units.
MDSetWaveUnits	Sets units for the specified dimension or data units.
MDSetDimensionLabel	Sets dimension label for specified dimension index.
SetWaveDimensionLabels	Sets all dimension labels for entire wave.
SetWaveNote	Sets the wave note.
SetWaveLock	Sets the lock state of the wave.

Reading Wave Data

Routine	Description
WaveData	Returns pointer to the start of wave's data.
MDAccessNumericWaveData	Returns the offset to the wave data.
MDGetNumericWavePointValue	Returns the value of a single element of wave.
MDGetDPDataFromNumericWave	Returns all wave data in a double-precision buffer.
MDGetTextWavePointValue	Gets the value of a single element of text wave.
GetTextWaveData	Gets the entire contents of a text wave.

Writing Wave Data

Routine	Description
WaveData	Returns pointer to the start of wave's data.
MDAccessNumericWaveData	Returns the offset to wave data.
MDSetNumericWavePointValue	Sets the value of a single element of wave.
MDStoreDPDataInNumericWave	Sets all wave data from a double-precision buffer.
MDSetTextWavePointValue	Sets the value of a single element of text wave.
SetTextWaveData	Sets the entire contents of a text wave.

Wave Reference Counting

Routine	Description
HoldWave	Tells Igor that you are holding a wave handle until further notice.
ReleaseWave	Tells Igor that you are no longer holding a wave handle.

Example

Here is a simple example that illustrates creating a wave, filling it with values and setting a wave property. The underlined items are data types, functions, constants or structures defined in the XOPSupport library and headers.

```
static int
MakeWave0(void)
{
   waveHndl waveH;
   char waveName[MAX_OBJ_NAME+1];
   DataFolderHandle dfH;
   CountInt dimensionSizes[MAX_DIMENSIONS+1];
   float* wp;
   IndexInt p;
   double offset, delta;
   int err;

   strcpy(waveName, "wave0");
   dfH = NULL;                  // Put wave in the current data folder
   MemClear(dimensionSizes, sizeof(dimensionSizes));
   dimensionSizes[ROWS] = 100;  // Make 1D wave with 100 points
   if (err = MDMakeWave(&waveH, waveName, dfH, dimensionSizes, NT_FP32, 1))
      return err;

   wp = (float*)WaveData(waveH); // Get a pointer to the wave data
   for(p = 0; p < 100; p++)
      *wp++ = p;                // Store point number in wave

   offset = 0; delta = .001;    // Set X scaling to .001/point
   if (err = MDSetWaveScaling(waveH, ROWS, &delta, &offset))
      return err;

   return 0;
}
```

This routine makes a 100 point, single-precision (NT_FP32) 1D wave. The letters "MD" in some of the XOP-Support routine names indicate that the routine is capable of dealing with multi-dimensional as well as 1D waves.

We get a pointer to the main wave data using the XOPSupport **WaveData** routine and use the pointer to store a value in each element of the wave.

This code is capable of dealing with single-precision numeric data only. You will see below that waves can contain one of 10 floating point and integer numeric data types, can be real or complex, and also can contain text, wave references and data folder references. An XOP programmer can choose to support all of these types or just some of them. XOPSupport routines described below provide ways to access wave data of any type.

Wave Data Types

Waves can have one of the following data types:

Symbol	Decimal Value	Bytes Per Element	Description
NT_FP64	4	8	Double-precision floating point (double).
NT_FP32	2	4	Single-precision floating point (float).
NT_I64	128	8	Signed 64-bit integer (SInt64).
NT_I32	32	4	Signed 32-bit integer (SInt32).
NT_I16	16	2	Signed 16-bit integer (short).
NT_I8	8	1	Signed 8-bit integer (char).
NT_I64 | NT_UNSIGNED	128+64	8	Unsigned 64-bit integer (UInt64).
NT_I32 | NT_UNSIGNED	32+64	4	Unsigned 32-bit integer (UInt32).
NT_I16 | NT_UNSIGNED	16+64	2	Unsigned 16-bit integer (short).
NT_I8 | NT_UNSIGNED	8+64	1	Unsigned 8-bit integer (char).
TEXT_WAVE_TYPE	0	variable	Unsigned 8-bit integer (char).
WAVE_TYPE	16384	4 or 8	Wave reference (waveHndl)
DATAFOLDER_TYPE	256	4 or 8	Data folder reference (DataFolderHandle)

Any of the numeric types can be ORed with NT_CMPLX to specify a complex data type. For example, (NT_FP32 | NT_CMPLX) represents complex, single-precision floating point, has a decimal value of 2+1 and takes 2*4 bytes per element. Text, wave reference and data folder reference waves can not be complex.

Wave references and data folder references are handles. A handle is a form of pointer and therefore consists of 4 bytes when running in 32 bits and 8 bytes when running in 64 bits.

As illustrated in the following sections, you can write your XOP to handle any data type or to require specific data types.

Accessing Numeric Wave Data

This section describes how Igor stores numeric wave data and how you can use the XOPSupport wave access routines to access the data. The routines mentioned here are described in detail in Chapter 15. The WaveAccess sample XOP illustrates how to use them.

The XOP Toolkit supports three different ways to access the numeric data in waves of dimension 1 through 4. The **point access** method is the easiest and the slowest. The **direct access** method is the hardest and the fastest. The **temporary storage** method is not too hard and reasonably fast. This section discusses how to choose which method to use.

The Point Access Method

The easiest method is to use the **MDGetNumericWavePointValue** and **MDSetNumericWavePointValue** routines to access a single wave point at a time. For example:

```
IndexInt indices[MAX_DIMENSIONS];
double value[2];           // real part and imag part (if wave is complex)
int result;

MemClear(indices, sizeof(indices));    // Clear unused dimensions.
indices[0] = row;
indices[1] = column;
if (result = MDGetNumericWavePointValue(waveH, indices, value))
   return result;
value[0] += 1;                          // Add one to real part
if (result = MDSetNumericWavePointValue(waveH, indices, value))
   return result;
```

This example assumes that the wave has two dimensions and changes a value in a given row and column.

This method is simple because you deal with indices, not with pointers, and you don't need to worry about the numeric type of the data. The XOPSupport routines do any numeric conversions that are needed. It will continue to work with future versions of Igor that support additional numeric types or use a different organization of data in memory. The downside of this method is that it is not as fast as possible. The reason for this is that, each time you call either of the routines, it must calculate the address of the wave data specified by the indices and then must convert the data to or from double-precision floating point (unless the wave is already double precision).

When storing into an integer wave, MDSetNumericWavePointValue truncates the value that you are storing. If you want, you can do rounding before calling MDSetNumericWavePointValue.

Unless your application deals with large arrays and/or accesses the same data points over and over and over again, the speed penalty will not be very noticeable and the point access method is a good one to choose. This is also the recommended method if you are not comfortable dealing with pointers.

MDGetNumericWavePointValue and MDSetNumericWavePointValue use doubles which can not precisely represent integers of magnitude greater than 2^53. If you must use 64-bit integer waves and require full precision for very large values, you must use **The Direct Access Method** (see page 126) or these routines which require Igor Pro 7.03 or later:

MDGetNumericWavePointValueSInt64	**MDSetNumericWavePointValueSInt64**
MDGetNumericWavePointValueUInt64	**MDSetNumericWavePointValueUInt64**

See **64-bit Integer Issues** on page 204 for further discussion.

The Temporary Storage Access Method

In the temporary storage access method, you use **MDGetDPDataFromNumericWave** and **MDStoreDPDataInNumericWave** to transfer data between the wave and a temporary storage buffer that you create. For example:

```
BCInt numBytes;
double* dPtr;
double* dp;
int result;

numBytes = WavePoints(waveH)*sizeof(double);          // Bytes needed for copy
if (WaveType(waveH) & NT_CMPLX)// Complex data?
   numBytes *= 2;
dPtr = (double*)WMNewPtr(numBytes);
if (dPtr==NULL)
```

```
   return NOMEM;
if (result = MDGetDPDataFromNumericWave(waveH,dPtr)) {// Get copy.
   WMDisposePtr((Ptr)dPtr);
   return result;
}
dp = dPtr;
<Use dp to access wave data.>
result = MDStoreDPDataInNumericWave(waveH,dPtr);      // Store data.
WMDisposePtr((Ptr)dPtr);
```

The data in the buffer is stored in row/column/layer/chunk order. This is explained in more detail **Organization of Numeric Data in Memory** on page 127.

Since the data in the buffer is always double-precision, regardless of the numeric type of the wave, this method relieves you of having to deal with multiple data types and will continue to work with future versions of Igor that support additional numeric types. It will also work with future versions of Igor that use a different organization of data in memory.

When storing into an integer wave, MDStoreDPDataInNumericWave truncates the value that you are storing. If you want, you can do rounding before calling MDStoreDPDataInNumericWave .

The disadvantage of this method is that it requires additional memory to hold the temporary copy of the wave data. You also pay a small speed penalty for copying the data.

If you are comfortable with memory allocation and deallocation and with pointers to double-precision data and if you are not willing to deal with the complexity of the direct access method (described below), then the temporary storage method is recommended for you.

The temporary storage access method uses doubles which can not precisely represent integers of magnitude greater than 2^53. If you must use 64-bit integer waves and require full precision for very large values, you must use **The Direct Access Method**, described in the next section. See **64-bit Integer Issues** on page 204 for further discussion.

The Direct Access Method

The fastest and most difficult method is to use the **MDAccessNumericWaveData** routine to find the offset from the start of the wave handle to the numeric data. For example:

```
BCInt dataOffset;
double* dp;
int result;

if (result=MDAccessNumericWaveData(waveH, kMDWaveAccessMode0, &dataOffset))
   return result;
dp = (double*)((char*)(*waveH) + dataOffset);// DEREFERENCE
```

At this point, dp points to the numeric data in the wave. The data in the buffer is stored in row/column/layer/chunk order. This is explained in more detail under **Organization of Numeric Data in Memory** on page 127. See Chapter 15 for an example illustrating the use of MDAccessNumericData.

There are three difficulties in using the direct access method.

The first and greatest difficulty is that you need to take into account the data type of the wave. Igor numeric waves can be one of the 10 numeric types listed above. You need a different type of pointer to deal with each of these data types. This is illustrated in the example for MDAccessNumericWaveData in the WaveAccess sample XOP. If you are using C++, you can use a template to handle all of the data types.

The second difficulty is that, because you are pointing directly to the wave data, you need to know the layout of the data in memory. If a future version of Igor changes this layout (not very likely), your XOP will no longer work. Your XOP will not crash in that event, because the MDAccessNumericWaveData routine will see that you have passed it “kMDWaveAccessMode0”. It will deduce from this that your XOP is treating the data in a way which, in the future version of Igor, is no longer appropriate. Thus, MDAccessNumericWaveData will return a non-zero error code result which your XOP will return to Igor. You will see an error alert in Igor telling you that your XOP is obsolete and needs to be updated. Using the WaveData XOPSupport routine is functionally equivalent to using MDAccessNumericWaveData except that WaveData does not provide this compatibility check.

The last difficulty involves resizing the wave which you do by calling **ChangeWave**, **MDChangeWave** or **MDChangeWave2**. When you increase the size of a wave, the memory manager may be required to move the block of memory holding the wave's data in order to enlarge it. If that happens, any pointer to the wave data that you previously acquired, such as the dp variable shown above, becomes a dangling pointer - pointing to something that is no longer there. You must set the pointer again to make sure that it points to the waves data. See **Dangling Pointers** on page 216 for further discussion.

Speed Comparisons

The WaveAccess sample XOP implements routines that fill a 3D wave using each of the wave access methods described above. To try them, compile the WaveAccess XOP and install it in the Igor Extensions folder. Launch Igor Pro and execute the following commands:

```
Make/N=(50,50,50) wave3D
Variable timerRefNum

// Enter the next three lines as one command line
timerRefNum = StartMSTimer
WAFill3DWaveDirectMethod(wave3D)
Print StopMSTimer(timerRefNum)/1e6
```

Repeat replacing WAFill3DWaveDirectMethod with WAFill3DWavePointMethod and WAFill3DWaveStorageMethod.

The following times were recorded for filling a 200x200x200 double-precision wave using the release build of WaveAccess. All tests were run on a 2010-vintage MacBook Pro with an Intel i7 laptop processor running at 2.66GHz

Operating System	Direct Access	Temp Storage	Point Access
MacOS 10.6.3	0.018 s	0.086 s	0.214 s
Windows 7/64	0.031	0.103	0.176
Windows 7/64 Under VMWave Fusion	0.037	0.124	0.181

Organization of Numeric Data in Memory

Using the direct or temporary storage wave access methods provides you with a pointer to wave data in memory. You need to know how the data is organized so that you can access it in a meaningful way.

The pointer that you get using the direct access method is a pointer to the actual wave data in the block of memory referenced by the wave handle. The pointer that you get using the temporary storage method is a pointer to a copy of the data. Data is organized in the same way in each of these methods.

Numeric wave data is stored contiguously in one of the supported data types. To access a particular element, you need to know the number of elements in each dimension. To find this, you must call **MDGetWaveDimensions**. This returns the number of used dimensions in the wave and an array of dimension lengths. The dimension lengths are interpreted as follows:

Item	Meaning
`dimensionSizes[ROWS]`	Number of rows in a column.
`dimensionSizes[COLUMNS]`	Number of columns in a layer. Zero for 1D waves.

Item	Meaning
`dimensionSizes[LAYERS]`	Number of layers in a chunk. Zero for 1D and 2D waves.
`dimensionSizes[CHUNKS]`	Number of chunks in the wave. Zero for 1D, 2D and 3D waves.

The symbols ROWS, COLUMNS, LAYERS and CHUNKS are defined in IgorXOP.h as 0, 1, 2 and 3 respectively.

For a wave of n dimensions, dimensionSizes[0..n-1] will be non-zero and dimensionSizes[n] will be zero.

The data is stored in row/column/layer/chunk order. This means that, as you step linearly through memory one point at a time, you first pass the value for each row in the first column. At the end of the first column, you reach the start of the second column. After you have passed the data for each column in the first layer, you reach the data for the first column in the second layer. After you have passed the data for each layer, you reach the data for the first layer of the second chunk. This ordering is called “column-major order”.

If the data is complex, the real and imaginary part of each data point are stored contiguously, with the real part first.

Accessing Text Wave Data

This section describes how Igor stores text data and how you can use the XOPSupport wave access routines to access the data. The routines mentioned here are described in detail in Chapter 15. The WaveAccess sample XOP illustrates how to use them.

Each element of a text wave can contain any number of characters. There are no illegal characters. However, if you store a binary 0 in a text wave element, Igor operations and functions, such as Print and sprintf, which treat the element as a C string, will treat the 0 byte as the end of the string.

The organization of wave text data in memory is an implementation detail of Igor and you code can not depend on it.

Igor6 stored all of the data for a text wave in the block of memory referenced by the wave handle, after the wave structure information. The wave structure contained another handle in which Igor stores indices. The indices told Igor where the text for any given element in the text wave began.

As of Igor7, Igor stores each text wave element in a separate block of memory referenced by a separate pointer. This makes insertions and deletions much faster at the expense of greater memory usage.

You should not attempt to access the text data or the text indices directly. Instead, use the XOPSupport routines provide for getting and setting the contents of an element of a text wave. For example, here is a section of the WAModifyTextWave routine in WaveAccess.cpp:

```
indices[1] = column;
for(row=0; row<numRows; row++) {
   indices[0] = row;
   if (result = MDGetTextWavePointValue(waveH, indices, textH))
      goto done;
   <Modify the text in textH>;
   if (result = MDSetTextWavePointValue(waveH, indices, textH))
      goto done;
}
```

MDGetTextWavePointValue gets the contents of a particular element of the text wave which in this example is a 2D wave. The contents are returned via the pre-existing textH handle. textH is allocated by and belongs to the calling XOP, not to Igor.

textH contains just the characters in the specified element of the text wave. It does not contain a count byte, a trailing null character or any other information. To find the number of characters in the element, use WMGetHandleSize. If you want to treat the contents of the handle as a C string, you must null-terminate it first. Remember to remove the null terminator if you pass this handle back to Igor. For further discussion see **Understand the Difference Between a String in a Handle and a C String** on page 221.

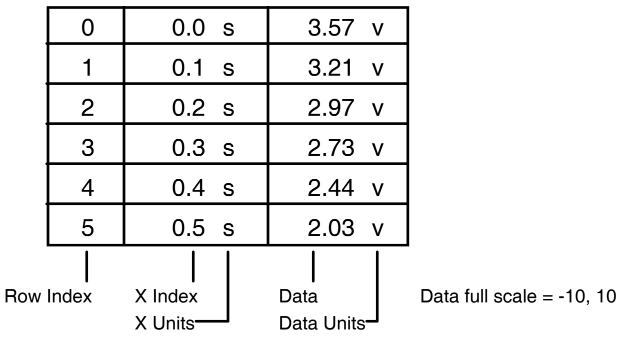
If you can tolerate setting a maximum length for an element, you can use the XOPSupport **GetCString-FromHandle** and **PutCStringInHandle** to move the text between the handle and a C string which is easier to deal with. Using this technique, you don't need to worry about adding or removing null terminators.

MDSetTextWavePointValue sets the specified element of the text wave. textH still belongs to the calling XOP. Igor just copies the contents of textH into the wave.

For dealing with the entire contents of large text waves, MDGetTextWavePointValue and MDSetTextWave-PointValue may be too slow. You can use the faster but more complicated **GetTextWaveData** and **SetTex-tWaveData** routines which are described in Chapter 15.

Wave Scaling and Units

A wave has units and scaling for each dimension. In addition, it has units and full scale values for the data stored in the wave. Consider the following example of a 1D wave which stores voltage versus time:

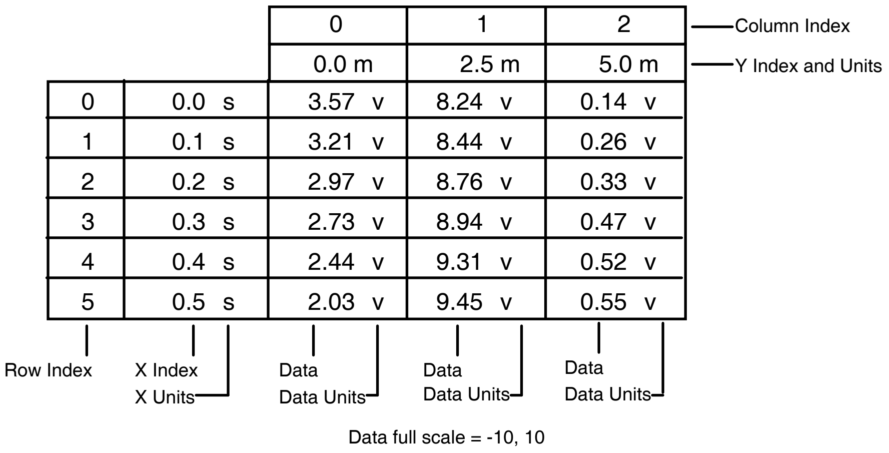


0	0.0 s	3.57 v
1	0.1 s	3.21 v
2	0.2 s	2.97 v
3	0.3 s	2.73 v
4	0.4 s	2.44 v
5	0.5 s	2.03 v

For a 1D wave, the row indices are also called point numbers. The X indices are calculated by Igor from the row indices using the scaling information for dimension 0 of the wave. You can set this scaling using a "Set-Scale x" command from within Igor and using the **MDSetWaveScaling** XOPSupport routine from an XOP. You can set the X units using a "SetScale x" command from within Igor and using the **MDSetWaveUnits** operation XOPSupport routine from an XOP.

You can set the data units and data full scale values using a "SetScale d" command from within Igor and using the **SetWaveUnits** and **SetWaveScaling** XOPSupport routines from an XOP. The data full scale is not analogous to the X scaling information. It merely is a record of the nominal full scale value for the data. For example, if you acquired the data using a digital oscilloscope set to the +/- 10V range, you can record this in the data full scale property of the wave. If this is not appropriate for your data, you can ignore the data full scale.

Considering a 2D wave, we see that the concepts of row indices, X indices and X units are extended to 2 dimensions, yielding column indices, Y indices and Y units.



		0	1	2
		0.0 m	2.5 m	5.0 m
0	0.0 s	3.57 v	8.24 v	0.14 v
1	0.1 s	3.21 v	8.44 v	0.26 v
2	0.2 s	2.97 v	8.76 v	0.33 v
3	0.3 s	2.73 v	8.94 v	0.47 v
4	0.4 s	2.44 v	9.31 v	0.52 v
5	0.5 s	2.03 v	9.45 v	0.55 v

You can set both the X (row) and Y (column) units and scaling using a SetScale command from within Igor and using the **MDSetWaveUnits** and **MDSetWaveScaling** XOPSupport routines from an XOP. If we extend to three dimensions, we add Z (layer) units and scaling and still use the same routines to set them.

Note that, as you go from 1D to 2D, you still have only one data units string and one data full scale. This is true no matter how many dimensions your wave has.

Killing Waves

You can kill a wave using the **KillWave** XOPSupport routine. Once you have killed a wave, you must not use any wave handle referencing it.

Igor disallows the killing of a wave that is displayed in a graph or table or used in a dependency formula. If you try to kill such a wave, you will receive an error.

Igor itself, the Igor user, a user-defined procedure or another XOP can also kill a wave. This can happen while your XOP code is running only if you do a callback to Igor. Most callbacks will not kill any waves but some, such as **XOPCommand** or **CallFunction**, can call user procedures which can do anything.

You can prevent the killing of a wave by responding to the OBJINUSE message, as described in the next section.

If a wave is killed and you subsequently use a wave handle referencing the killed wave, a crash is likely to occur.

Preventing the Killing of a Wave

As Igor disallows the killing of a wave displayed in a graph, which would undermine the graph, you may want to disallow the killing of a wave that you are using over an indefinite period, such as a wave into which you are acquiring data. You can do this by responding to the OBJINUSE message.

Before killing a wave, Igor sends the OBJINUSE message to each XOP. If the XOP reports that the wave is in use, Igor refuses to kill it.

The OBJINUSE message is sent to XOPs only from the main Igor thread. It is not sent when an Igor preemptive thread is executing because the XOP message protocol is not threadsafe.

Responding to the OBJINUSE message prevents a wave from being *killed* while another technique, wave reference counting discussed on page 131, prevents it from being *deleted*. Wave reference counting is especially important if you are doing multithreading. It is discussed in the next section.

If your code may deal with waves from both the main Igor thread and a preemptive Igor thread, and if there is any chance that the wave may be killed while you are holding a reference to it, you should use both the OBJINUSE message and wave reference counting.

When a new experiment is loaded or Igor quits, all objects are killed, whether they are in use or not. Therefore, if your XOP holds a handle to a wave, it must clear that handle and cease accessing the wave when Igor sends you the NEW or CLEANUP messages.

See page 57 for further discussion of the OBJINUSE message.

Wave Reference Counting

The information in this section is needed only for advanced XOPs.

Internally in Igor, a wave reference is a memory location that contains a waveHndl.

An Igor user can create a wave reference by executing a WAVE statement in a user-defined function, by passing a wave as a parameter from one user-defined function to another, by setting a WAVE field in a structure and by setting an element of a wave wave. (A wave wave is a wave containing wave references created by Make/WAVE.)

An XOP holds a reference to a wave in a waveHndl variable.

If the underlying wave is deleted and Igor or an XOP subsequently attempts to use the waveHndl variable, a crash results. A technique is needed to prevent such crashes.

Internally Igor uses reference counting to determine when there are no more references to a wave in which case it is safe to delete it. The **HoldWave** and **ReleaseWave** XOPSupport routines allow XOPs to participate in reference counting.

When a regular (non-free) wave is created, Igor links the wave into its data folder. This link consitutes a reference to the wave, so Igor sets the wave’s reference count to 1.

By contrast, a free wave is not part of any data folder. Therefore its reference count at creation is 0.

HoldWave increments the reference count of a wave. ReleaseWave decrements it and, if the count goes to zero or below, deletes the wave.

Killing Versus Deleting a Wave

There is a subtle distinction between *killing* a wave and *deleting* it. "Killing" means unlinking a wave from its data folder so that it no longer appears in the data hierarchy. "Deleting" means freeing the memory holding the wave's structure and data. Though we usually think of deleting as an integral part of killing, a wave can be killed without being immediately deleted.

Understanding this distinction helps to understand the purpose and mechanics of wave reference counting. This example user-defined function may clarify the distinction:

```
Function Test()
   String name = "jack"

   // Igor creates wave jack and sets the reference count to 0.
   // Igor then links jack into the current data folder.
   // The link constitutes a reference to the wave so Igor
   // increments the reference count to 1.
   Make/O/N=10 $name = p

   // We create another reference to the wave and the reference count
   // is incremented to 2.
   Wave w = $name

   Print WaveExists(w), WaveType(w)    // Verify that the wave is alive

   // We create another reference to the wave and the reference count
   // is incremented to 3.
   Wave w2 = $name
   // This statement unlinks the wave from the data folder AND clears w
   // but w2 still references the wave. The unlinking and the clearing
   // both decrement the reference count so it winds up at 1.
   // Because it is not zero, the wave is not deleted.
   KillWaves w

   // This statement prints "0,0" because a killed wave is considered
   // to not exist even though it has not yet been deleted.
   Print WaveExists(w2), WaveType(w2)
End   // w2 goes out of scope. Igor decrements the reference count to 0
      // and the wave is deleted.
```

Reference counting prevents the untimely deletion of a wave but does not prevent it from being killed. The OBJINUSE message, discussed under **Preventing the Killing of a Wave** on page 130, prevents a wave from being killed.

If your code may deal with waves from both the main Igor thread and a preemptive Igor thread, and if there is any chance that the wave may be killed or deleted while you are holding a reference to it, you should use both the OBJINUSE message and wave reference counting.

XOPs and Wave Reference Counting

An XOP may "hold" a wave handle. "Hold" means that you are storing a waveHndl over a period of time during which Igor could possibly delete it. **HoldWave** allows you to tell Igor that the wave should not be deleted until you subsequently call **ReleaseWave**.

For example, a data acquisition XOP that stores data in a wave during IDLE messages would typically store the wave handle in a global variable and write to that wave each time it receives an IDLE message. It is important that Igor not delete the wave while the XOP is holding a reference to it.

This example illustrates the use of HoldWave/ReleaseWave in a simple data acquisition application:

```
static waveHndl gWaveH = NULL;   // Global to hold data acq wave

int
StartAcq()           // Called from your StartAcq operation or function
{
   gWaveH = FetchWave("jack");
   if (gWaveH == NULL)
      return NOWAV;

   // Tell Igor we are holding this wave handle
   HoldWave(gWaveH);

   . . .
}

int
DoAcq()              // Called from IDLE message
{
   if (gWaveH == NULL)
      return NOWAV;  // gWaveH should not be NULL during data acq
   . . .             // Acquire data into the wave
}

int
EndAcq()             // Called from your EndAcq operation or function
{
   if (gWaveH == NULL)
      return DATA_ACQ_NOT_RUNNING;

   // Tell Igor we are no longer holding a reference to the wave
   ReleaseWave(&gWaveH);      // NOTE: Sets gWaveH to NULL
   . . .
}
```

Note that ReleaseWave sets your wave handle (gWaveH in this example) to NULL and it is no longer valid.

You also should call HoldWave and ReleaseWave if you are doing a callback to Igor and the callback could possibly delete the wave - for example, if you are doing an **XOPCommand** callback or a **CallFunction** callback to run a user-defined function that could kill the wave. This is needed because you are holding a reference to the wave over a period of time in which it could be deleted.

If you are just using the wave handle temporarily during the execution of your external function or operation and you make no calls that could potentially delete the wave then you do not need to and should not call HoldWave and ReleaseWave.

If you are not sure if the wave could be deleted while you are holding it, call HoldWave/ReleaseWave. The extra pair of calls will do no harm besides the time they take.

Pass-By-Reference Wave Parameters and Wave Reference Counting

With Igor Pro 8.00 or later, you can define an external function that takes a pass-by-reference wave reference parameter.

Passing a wave reference *by reference* transfers ownership of the wave from the subroutine to the calling routine. This requires the proper use of wave reference counting via HoldWave and ReleaseWave.

For further discussion and an example, see **Pass-By-Reference Wave Reference Parameters** on page 113.

Structure Parameters and Wave Reference Counting

Normally you will call both HoldWave and ReleaseWave yourself but there is an infrequently encountered case where Igor will call ReleaseWave instead of you.

If you define an external function or operation with a structure parameter and the structure contains a WAVE field and your XOP returns a wave handle to the calling user-defined function by setting the WAVE field, you must call HoldWave on the wave because the WAVE field holds a new reference to the wave.

You then return to the calling user-defined function. When it finishes and the structure goes out of scope, Igor calls ReleaseWave on the structure WAVE field. In this case, you are passing responsibility for reference counting to the calling user-defined function which is then responsible for matching your HoldWave with its own ReleaseWave.

If the WAVE field previously held a wave reference then Igor will have previously called HoldWave on the wave. By storing into the field, you are eliminating a reference to whatever wave was previously referenced so you must release the previous wave reference first.

Putting it all together, your code would look like this:

```
// Structure of parameter to external operation or function.
struct WaveRefExampleStruct {
   waveHndl waveH;            // Input wave and output wave reference
};
typedef struct WaveRefExampleStruct WaveRefExampleStruct;

// Parameter structure sent from Igor to XOP
struct WaveRefExampleParam {
   WaveRefExampleStruct* sp;  // Pointer to a user-defined structure
   double result;
};
typedef struct WaveRefExampleParam WaveRefExampleParam;

// Called from Igor by: result = WaveRefExample(<structure>)
```

```
int WaveRefExample(struct WaveRefExampleParam* p)
{
   struct WaveRefExampleStruct* sp;
   waveHndl newWaveH;
   int err = 0;

   sp = p->sp;
   if (sp == NULL)  {
      err = EXPECT_STRUCT;
      goto done;
   }

   newWaveH = FetchWave("jack");    // NULL if jack does not exist

   if (sp->waveH != newWaveH) {     // No release or hold needed if same
      // We are going to store a wave handle in sp->waveH. This constitutes
      // a new reference to that wave. But there may already be a wave handle
      // in sp->waveH. In that case, storing into sp->waveH eliminates
      // a reference to the original wave so we must release it.

      // Sets sp->waveH to NULL. Does nothing if sp->waveH is already NULL.
      ReleaseWave(&sp->waveH);      // Release original wave if any

      sp->waveH = newWaveH;         // NULL if jack does not exist

      // Structure field constitutes a new reference to wave jack
      if (sp->waveH != NULL)
         HoldWave(sp->waveH);       // Hold wave referenced by structure field
   }

done:
   p->result = err;

   // We now return to the calling user-defined function which is
   // responsible for calling ReleaseWave on sp->waveH.

   return err;
}
```

New Experiment and Wave Reference Counting

When an experiment is closed, either through New Experiment, opening another experiment or quitting Igor, all waves are killed whether you are holding them or not. Consequently, you must do something like this when your XOPEntry routine receives the NEW or CLEANUP message:

```
case NEW:          // New experiment
case CLEANUP:      // About to quit
   // Wave about to be killed. Make sure global reference is NULL.
   if (gWaveH != NULL)
      ReleaseWave(&gWaveH);   // Sets gWaveH to NULL
```

When Igor is quitting, Igor6 did not send the NEW message but sent the CLEANUP message before all waves and data were killed.

When Igor is quitting, Igor7 and later do send the NEW message before all waves and data are killed and send the CLEANUP message after all waves and data are killed.

Wave Reference Waves

A wave reference wave is a wave that contains references to other waves in the form of waveHndls. Such a wave can be used, for example, to pass a variable length list of waves to a user-defined function. The contents of a given element of a wave reference wave is a wave handle or NULL.

You can create a wave reference wave by passing WAVE_TYPE as the dataType parameter to **MakeWave** and **MDMakeWave**.

Igor does not permit making complex wave reference waves.

Use the **HoldWave** callback routine after storing a wave handle in a wave reference wave element. To clear an element, use **ReleaseWave**. Using HoldWave and ReleaseWave is necessary to maintain the integrity of Igor's internal reference counting mechanism.

Data Folder Reference Waves

A data folder reference wave is a wave that contains references to data folders in the form of DataFolder-Handles. Such a wave can be used, for example, to pass a variable length list of data folders to a user-defined function. The contents of a given element of a data folder reference wave is a data folder handle or NULL.

You can create a data folder reference wave by passing DATAFOLDER_TYPE as the dataType parameter to **MakeWave** and **MDMakeWave**.

Igor does not permit making complex data folder reference waves.

Use the **HoldDataFolder** callback routine after storing a data folder handle in a data folder reference wave element. To clear an element, use **ReleaseDataFolder**. Using HoldDataFolder and ReleaseDataFolder is necessary to maintain the integrity of Igor's internal reference counting mechanism.

Free Waves

Free waves are temporary waves that are not part of Igor's data hierarchy. They are created in user-defined functions and cease to exist when the function returns. You should create a free wave when the user requests it through a /FREE flag or some other parameter or when you need a wave for your own temporary use.

You can make a free wave using **MDMakeWave** but it is more common to make a free wave as a destination wave using **GetOperationDestWave**.

Free Waves and Wave Reference Counting

The lifetime of a free wave, like that of a regular (non-free) wave, is controlled by its reference count. See **Wave Reference Counting** on page 131 for background information.

When a regular wave is created, Igor links the wave into its data folder. This link consitutes a reference to the wave, so Igor sets the wave's reference count to 1.

By contrast, a free wave is not part of any data folder. Therefore its reference count at creation is 0.

When you create a free wave, you must call **HoldWave** on it to increment the reference count, and then, when you are finished with it, call **ReleaseWave** to decrement the reference count.

Igor deletes the wave (free or regular) when its reference count is decremented to 0 or below. The reference count is decremented when you call **ReleaseWave** or **KillWave**. It can also be decremented by Igor, the user or another XOP if they have access to the free wave's handle.

Using reference counting, through HoldWave and ReleaseWave rather than KillWave, is the preferred approach for free waves. However, KillWave does internally call ReleaseWave which decrements the wave's reference count and, if the count goes to zero or below, deletes it.

You can determine if a wave is a free wave by calling **GetWavesDataFolder**. If it returns a NULL data folder handle then the wave is free.

Free Wave Reference Counting Examples

To help you think about free waves and reference counting, here are some examples. "wRefCount" is used to represent Igor's internal reference count for a wave.

In the first example, a user-defined function creates a free wave and passes it to an XOP which uses it only during the external function call. The external function call does not do any callbacks to Igor that could cause the reference count to be decremented. The XOP does not need to call HoldWave/ReleaseWave.

```
Function Example1()
   // A free wave is created. wRefCount = 0.
   // A reference to the wave is stored in w. wRefCount = 1.
   Wave w = NewFreeWave(10,2)

   // The free wave is passed to an XOP which uses it only momentarily.
   XOPFunction1(w)
End   // w goes out of scope, wRefCount is decremented to 0, wave is deleted.
```

Although there is no need for the XOP to call HoldWave/ReleaseWave, doing so would not cause a problem other than taking some time.

In the next example, a user-defined function creates a free wave and passes it to an XOP which copies it to a global variable and then returns to Igor. The XOP later accesses the wave through the global variable. Because it is holding a wave reference over a period of time during which it could be deleted, the XOP must call HoldWave.

```
Function Example2()
   // A free wave is created. wRefCount = 0.
   // A reference to the wave is stored in w. wRefCount = 1.
   Wave w = NewFreeWave(10,2)

   // The free wave is passed to an XOP which stores it in a global waveHndl.
   // The XOP calls HoldWave on it. wRefCount = 2.
   XOPFunction2(w)
End   // w goes out of scope, wRefCount is decremented to 1.
      // Since wRefCount > 0, the wave is not deleted.

   ...   // Time passes during which the XOP receives IDLE messages.
         // The XOP access the wave during these messages.

   // The XOP, finished with the wave, calls ReleaseWave on the global waveHndl.
   // wRefCount goes to 0 and the wave is deleted.
```

Storing the wave handle in the global variable constitutes holding a reference to the wave. Therefore the XOP must call HoldWave. If it did not, when the Example2 user-defined function returned, the wave would be deleted, leaving the XOP holding and invalid wave handle.

In the next example, the XOP creates a free wave for use during the invocation of an external function only.

```
   // Create free wave with wRefCount = 0.
   waveHndl freeWaveH;
   MDMakeWave(&freeWaveH, "free", (DataFolderHandle)-1,
                                             dimensionSizes, NT_FP64, 1);
   HoldWave(freeWaveH);        // wRefCount = 1.
   <Use freeWaveH>
   ReleaseWave(&freeWaveH);    // wRefCount = 0 and wave is deleted.
```

If the XOP does nothing that could possibly delete the wave, the call to HoldWave is not strictly required but it it is recommended since the code could later be changed such that the wave could be deleted.

If the XOP did not call ReleaseWave, the free wave would never be deleted and this would constitute a leak.

In the final example, the XOP creates a free wave and, using **CallFunction**, passes it to a user-defined function.

```
   // Create free wave with wRefCount = 0.
   waveHndl freeWaveH;
   MDMakeWave(&freeWaveH, "free", (DataFolderHandle)-1, dims, NT_FP64, 1);
   HoldWave(freeWaveH);       // wRefCount = 1

   <Pass freeWaveH to a user-defined function via CallFunction>
      Function UserFunction(w)
         Wave w   // Creation of wave parameter. wRefCount = 2.
         ...
      End         // w goes out of scope. wRefCount = 1.

   <XOP uses freeWaveH>

   ReleaseWave(&freeWaveH);   // wRefCount = 0 and wave is deleted.
```

In this case, if the XOP did not call HoldWave, wRefCount would go to 0 and the wave would be deleted prematurely when the user-defined function returned.

Numeric and String Variables

This section decribes accessing variables other than an Operation Handler operation's runtime output variables (e.g., V_flag). For information on setting runtime output variables see **Runtime Output Variables** on page 91. Except for that technique, it is not possible for an XOP to set a function local variable. This section pertains to global variables and macro local variables.

Unlike waves, global and macro local variables are not defined by handles. Instead, Igor maintains an internal table of variable names and values.

A numeric variable is always double-precision real (NT_FP64) or double-precision complex (NT_FP64 | NT_CMPLX).

The content of a string variable is stored in a block of memory referenced by a handle but this is not the same as a wave handle. In the case of the wave handle, the handle contains the wave structure as well as the wave data. Consequently, the wave handle completely defines a wave. In the case of a string variable, the handle contains just the variable's data. It does not contain the string variable's name or a reference to its data folder.

A string handle contains the string's text, with neither a count byte nor a trailing null byte. Use **WMGetHandleSize** to find the number of characters in the string. To use C string functions on this text you need to copy it to a local buffer and null-terminate it or add a null terminator to the handle. If you pass the handle back to Igor, you must remove the null terminator. For further discussion see **Understand the Difference Between a String in a Handle and a C String** on page 221.

If you can tolerate setting a maximum length for a string, you can use the XOPSupport **GetCStringFromHandle** and **PutCStringInHandle** to move the text between the handle and a C string which is easier to deal with. Using this technique, you don't need to worry about adding or removing null terminators.

The XOPSupport library provides routines to create variables, kill variables, get the value of variables and set the value of variables. All of these routines require that you pass the variable name to Igor. Some routines also allow you to specify the data folder in which the variable is to be created or found. Those routines that do not allow you to specify the data folder work in the current data folder.

Routines for Accessing Variables

The XOPSupport routines for dealing with variables are described under **Routines for Accessing Variables** on page 276. Here is a summary of the commonly-used routines.

Creating Variables

Routine	Description
Variable	Creates an Igor numeric or string variable.
	This routine is antiquated. The following routines are recommened.
SetIgorIntVar	Creates if necessary and then sets a numeric variable to an integer value.
SetIgorFloatingVar	Creates if necessary and then sets a numeric variable to a floating point value.
SetIgorComplexVar	Creates if necessary and then sets a numeric variable to a complex floating point value.
SetIgorStringVar	Creates if necessary and then sets a string variable.

Getting Variable Contents

Routine	Description
FetchNumVar	Gets the value of a numeric variable.
FetchStrVar	Gets up to 255 characters from a string variable.
FetchStrHandle	Gets any number of characters from a string variable.
GetDataFolderObject	Gets the value of numeric or string variable.

Setting Variable Contents

Routine	Description
StoreNumVar	Sets the value of a numeric variable.
SetIgorIntVar	Creates if necessary and then sets a numeric variable to an integer value.
SetIgorFloatingVar	Creates if necessary and then sets a numeric variable to a floating point value.
SetIgorComplexVar	Creates if necessary and then sets a numeric variable to a complex floating point value.
SetIgorStringVar	Creates if necessary and then sets a string variable.
SetFileLoaderOutputVariables	Specialized for file-loader XOPs.
SetFileLoaderOperationOutputVariables	Specialized for file-loader XOPs. Called from direct external operations only.
SetDataFolderObject	Sets the value of numeric or string variable.

Example

Here is a simple example that illustrates creating numeric and string variables and getting and setting their values. The underlined items are functions, constants or structures defined in the XOPSupport library and headers.

```
static int
MakeVariables(void)
{
   char varName[MAX_OBJ_NAME+1];
   double realVal, imagVal;
   char strValue[256];
   int err;

   strcpy(varName, "numVar0");
   realVal = 3.14159;
   if (err= SetIgorFloatingVar(varName, &realVal, 1)) // Create and set
      return err;
   if (FetchNumVar(varName, &realVal, &imagVal)==-1)  // Fetch value
      return EXPECTED_VARNAME;

   strcpy(varName, "strVar0");
   strcpy(strValue, "This is a string variable.");
   if (err= SetIgorStringVar(varName, strValue, 1))   // Create and set
      return err;
   if (err= FetchStrVar(varName, strValue))           // Fetch value
      return err;

   return 0;
}
```

The last parameter in the **SetIgorFloatingVar** and **SetIgorStringVar** routines requests that Igor make the variables global. If this parameter were zero and if our routine were called during the execution of a macro, Igor would make the variables local to the macro. You can not create a local variable in a user-defined function at runtime as these are created by Igor when the function is compiled.

For a discussion of creating output variables from an external operation, analogous to the V_ variables created by many Igor operations, see **Runtime Output Variables** on page 91.

The string part of this example uses routines that take and return C strings. This is easier than dealing with the actual string variable handle and is fine as long as the string variable contains 255 or fewer characters.

This example works in the current data folder. In most cases, this is the appropriate behavior.

Dealing With Data Folders

Data folders provide a way to store waves, numeric variables, string variables and other data folders in a hierarchy. Data folders are analogous to file system folders. However, data folders are maintained entirely by Igor.

If you save an Igor experiment in a packed experiment file, the entire data folder hierarchy is saved in the packed file. If you save an experiment in an unpacked file, Igor creates file system folders to mirror the data folder hierarchy. Because these file system folders are created only when you save an experiment unpacked, you should not assume that a file system folder exists to mirror any given Igor data folder. You should think of data folders as a hierarchy maintained by Igor in memory and saved to disk for storage purposes.

Igor stores information about a data folder in a DataFolderHandle. Each XOPSupport routine that deals with data folders returns a DataFolderHandle to you and/or requires a DataFolderHandle from you. You have no way of knowing and do not need to know the internal details of DataFolderHandles. They are black boxes. You merely receive them from Igor and pass them back to Igor. DataFolderHandles belong to Igor so you must not modify or dispose them.

When you get a DataFolderHandle from Igor, you typically use it momentarily and do not retain it. For most applications, you should avoid storing it long-term because it will become invalid if the user kills the data folder or opens a new experiment.

Routines for Accessing Data Folders

The XOPSupport routines for dealing with data folders are described in detail in Chapter 15. Most of them exist for the benefit of the Igor Data Browser, which is an XOP, and for other sophisticated XOPs. Here are the data folder routines that are most likely to be of use for a typical data-folder-aware XOP.

Getting a Handle to a Data Folder

Routine	Description
GetRootDataFolder	Returns a handle to the root data folder.
GetCurrentDataFolder	Returns a handle to the current data folder.
GetNamedDataFolder	Returns a handle to a data folder, given its name or path.
GetWavesDataFolder	Returns a handle to the data folder containing a particular wave.
GetParentDataFolder	Returns a handle to the parent of the specified data folder.
GetNumChildDataFolders	Returns the number of child data folders within a particular data folder.
GetIndexedChildDataFolder	Returns a handle to the specified data folder within a particular data folder.
GetDataFolderByIDNumber	Returns a handle to a data folder identified by an ID number that you previously obtained from **GetDataFolderIDNumber**.

Creating and Killing a Data Folder

Routine	Description
NewDataFolder	Creates a new data folder.
DuplicateDataFolder	Duplicates an existing data folder and its contents.
KillDataFolder	Kills a data folder.

Accessing Objects in a Data Folder

Routine	Description
GetNumDataFolderObjects	Returns the number of objects (waves, numeric variables, string variables, data folders) in a particular data folder.
GetIndexedDataFolderObject	Returns the name of a particular object.
GetDataFolderObject	Returns information about a particular object.
SetDataFolderObject	Sets information about a particular object.
KillDataFolderObject	Kills a particular object.
DuplicateDataFolderObject	Duplicates a particular object.

If you ignore the data-folder-related XOPSupport routines, your XOP will work in the current data folder. This is the appropriate behavior for many applications. Also, no special effort is required to work with existing waves in any data folder. Once you have the wave handle, you can manipulate the wave without knowing which data folder it resides in.

Data Folder Conventions

One of the points of using data folders is to reduce clutter. If your XOP requires a lot of private waves and/or variables, you should create a data folder to contain your private storage. By convention, data folders for this purpose are stored in another data folder named Packages which is in the root. This is discussed in the programming section of the Igor Pro manual.

Here is some code that will create a data folder for your private storage inside the Packages data folder.

```
static int
GetPrivateDataFolderHandle(char* dataFolderName, DataFolderHandle* dfHPtr)
{
   DataFolderHandle rootDFH, packagesDFH;
   int err;

   if (err = GetRootDataFolder(0, &rootDFH))
      return err;

   if (err = GetNamedDataFolder(rootDFH, "Packages", &packagesDFH)) {
      // We need to create Packages.
      if (err = NewDataFolder(rootDFH, "Packages", &packagesDFH))
         return err;
   }

   if (err = GetNamedDataFolder(packagesDFH, dataFolderName, dfHPtr)) {
      // We need to create our private data folder.
      if (err = NewDataFolder(packagesDFH, dataFolderName, dfHPtr))
         return err;
   }

   return 0;
}
```

You would call this routine like this:

```
DataFolderHandle privateStorageDFH;
if (err = GetPrivateDataFolderHandle("MyPrivateData", &privateStorageDFH))
   return err;
```

Of course, you should choose a name for your data folder that will make it clear what it is for and is specific enough to avoid conflicts with other packages.

Because the user can kill a data folder, intentionally or inadvertently, you should not store the data folder handle but instead should obtain it from Igor, as shown above, each time you need to use it. Another option is to use the **GetDataFolderIDNumber** and **GetDataFolderByIDNumber** routines, listed in Chapter 15. Advanced programmers may want to use data folder reference counting, described in the next section.

Data Folder Reference Counting

An XOP may "hold" a data folder handle. "Hold" means that you are storing a DataFolderHandle over a period of time during which Igor could possibly delete it.

Most XOPs have no need to hold data folders. The information in this section is needed only for advanced XOPs.

Igor keeps a reference count for each data folder. This count is used to determine if a data folder is in use.

XOPs can participate in data folder reference counting. If your XOP obtains a data folder handle and holds it after the XOP returns to Igor, you should call **HoldDataFolder** to increment Igor's internal reference count for that data folder. When you no longer need to access the data folder, you must call **ReleaseDataFolder**. ReleaseDataFolder decrements the data folder reference count and, if the count reaches zero, deletes the data folder.

For example, a data acquisition XOP that stores data in a data folder during IDLE messages might store the data folder handle in a global variable and write to that data folder each time it receives an IDLE message. It is important that Igor not delete a data folder while the XOP is holding a reference to it. To prevent the deletion, the XOP must call HoldDataFolder and then ReleaseDataFolder when you are finished with it.

You also should call HoldDataFolder and ReleaseDataFolder if you are doing a callback to Igor and the callback could possibly delete the data folder - for example, if you are doing an **XOPCommand** callback or a **CallFunction** callback to run a user-defined function that could kill the data folder. This constitutes "holding the data folder" because you are holding a reference to the data folder over a period of time in which it could be deleted. Therefore you should call HoldDataFolder to tell Igor you are using it and ReleaseDataFolder when you are no longer using it.

If you are just using the data folder handle temporarily during the execution of your external function or operation and you make no calls that could potentially delete the data folder then you do not need to and should not call HoldDataFolder and ReleaseDataFolder.

The code for holding and releasing a data folder is very similar to the code for holding and releasing a wave. See **Wave Reference Counting** on page 131 for sample code.

Pass-By-Reference Data Folder Parameters and Data Folder Reference Counting

With Igor Pro 8.00 or later, you can define an external function that takes a pass-by-reference data folder reference parameter.

Passing a data folder reference *by reference* transfers ownership of the data folder from the subroutine to the calling routine. This requires the proper use of data folder reference counting via HoldDataFolder and ReleaseDataFolder.

For further discussion and an example, see **Pass-By-Reference Data Folder Reference Parameters** on page 116.

Structure Parameters and Data Folder Reference Counting

Once you have called HoldDataFolder on a data folder, Igor will not delete it until ReleaseDataFolder has been called on it.

Normally you will call ReleaseDataFolder yourself but there is an infrequently-encountered case where Igor will call ReleaseDataFolder on it.

If you define an external function or operation with a structure parameter and the structure contains a DFREF field and your XOP returns a data folder handle to the calling user-defined function by setting the DFREF field, you must call HoldDataFolder on the data folder because the DFREF field holds a new reference to the data folder.

You then return to the calling user-defined function. When it finishes and the structure goes out of scope, Igor calls ReleaseDataFolder on the structure DFREF field. In this case, you are passing responsibility for reference counting to the calling user-defined function which is then responsible for matching your HoldDataFolder with its own ReleaseDataFolder.

If the DFREF field previously held a data folder reference then Igor will have previously called HoldDataFolder on the data folder. By storing into the field, you are eliminating a reference to whatever data folder was previously referenced so you must release the previous data folder reference first.

See **Structure Parameters and Wave Reference Counting** on page 133 for code showing how to put this all together in the case of a wave reference structure field. The pattern is the same for a data folder reference field.

New Experiment and Data Folder Reference Counting

When an experiment is closed, either through New Experiment, opening another experiment or quitting Igor, all data folders are killed whether you are holding them or not. Consequently, you must release any data folder that you are holding by calling ReleaseDataFolder when you receive the NEW or CLEANUP messages from Igor.

Chapter 8

Adding Menus and Menu Items

Overview

When Igor starts up, it examines each XOP file looking for resources that define menus, menu items and submenus that the XOP adds to Igor.

An XOP may elect to add no menus or menu items to Igor. For example, an XOP that does no more than add an operation or function to Igor does not need a menu or menu item. The XOP should contain none of the resources discussed below. If you are writing an XOP of this kind, you don't need to read this chapter.

A more elaborate XOP may need to add:

- A single menu item to a built-in Igor menu

  For example, an XOP that adds a number-crunching operation to Igor might want to simply add one menu item to Igor's Analysis menu.
- A single menu item to multiple built-in Igor menus

  For example, an XOP that allows Igor to load and save a particular file format might want to add one menu item to Igor's Load Waves menu and another menu item to Igor's Save Waves menu.
- A menu item with an attached submenu

  For example, an XOP that adds a family of number-crunching operations to Igor might want to add a submenu to Igor's Analysis menu.
- A menu in Igor's main menu bar

  For example, an XOP that adds significant functionality to Igor, such as a data acquisition system, might want to add a main menu bar menu.

An XOP adds menu items, submenus and main menu bar menus by defining resources that describe what is to be added and by responding to menu-related messages sent by Igor.

The MenuXOP1 sample XOP illustrates all of the scenarios listed above. It also shows how an XOP can determine which of its menu items has been selected and how to access each menu item to enable or disable it.

This chapter discusses many different ways for an XOP to use menus, submenus, and menu items. If your XOP merely adds a single unchanging menu item to Igor, you can skip down to the section **Adding Menu Items to Igor Menus** on page 150. This explains how to use an XMI1 resource to add a menu item. Then add code to your XOPEntry routine to respond when Igor sends a MENUITEM message. That is all you need to know to add a single menu item.

XOPSupport Menu Routines

This section gives a brief description of menu support routines provided by the XOPSupport library. You need to know this only if your XOP adds, removes, or modifies menus or menu items.

Most of these routines were added in XOP Toolkit 6.40 to replace ancient routines that were based on the Macintosh Menu Manager. If you are updating an old XOP, see "XOP Menus in XOP Toolkit 7" in Appendix A of the XOP Toolkit 7 manual.

Summary of XOPSupport Menu Routines

Here are the XOPSupport menu routines:

Routine	What It Does
ResourceToActualMenuID	Given the ID of a MENU resource in the XOP's resource fork, returns the actual menu ID of that menu in memory.
ActualToResourceMenuID	Given the ID of a menu in memory, returns the resource ID of the MENU resource in the XOP's resource fork.
ResourceToActualItem	Given the ID of a built-in Igor menu and the number of a menu item specification in the XMI1 resource in the XOP's resource fork, returns the actual item number of that item in the Igor menu.
ActualToResourceItem	Given the ID of a built-in Igor menu and the actual number of a menu item in the Igor menu, returns the number of the specification in the XMI1 resource in the XOP's resource fork for that item.
SetIgorMenuItem	Enables or disables a built-in Igor menu item.
XOPActualMenuIDToMenuRef	Given the actual menu ID of an XOP menu in memory, returns a menu reference for the XOP menu.
XOPResourceMenuIDToMenuRef	Given the ID of a MENU resource in the XOP's resource fork, returns a menu reference for that menu.
XOPGetMenuInfo	Returns information about a menu.
XOPCountMenuItems	Returns the number of items in a menu.
XOPShowMainMenu	Makes a menu appear in the menu bar if it was previously hidden.
XOPHideMainMenu	Removes the menu from the menu bar if it was previously showing.
XOPGetMenuItemInfo	Returns information about a menu item.
XOPGetMenuItemText	Returns the text from an XOP menu item.
XOPSetMenuItemText	Sets the text of an XOP menu item.
XOPAppendMenuItem	Adds a menu item to the end of an XOP menu.
XOPInsertMenuItem	Inserts a menu item in an XOP menu.
XOPDeleteMenuItem	Removes a menu item from an XOP menu.
XOPDeleteMenuItemRange	Removes a range of menu items from from an XOP menu.
XOPEnableMenuItem	Enables a menu item.
XOPDisableMenuItem	Disables a menu item.
XOPCheckMenuItem	Checks or unchecks a menu item.
XOPFillMenu	Inserts multiple items into an XOP menu.
XOPFillMenuNoMeta	Inserts multiple items into an XOP menu.
XOPFillWaveMenu	Inserts multiple wave names into an XOP menu.

Routine	What It Does
XOPFillPathMenu	Inserts multiple symbolic path names into an XOP menu.
XOPFillWinMenu	Inserts multiple window names into an XOP menu.

XOPMenuRefs

An XOPMenuRef is a pointer managed by Igor. Most XOPSupport menu routines take an XOPMenuRef as a parameter to identify the menu of interest. You obtain an XOPMenuRef for a menu that your XOP added to Igor by calling **XOPResourceMenuIDToMenuRef**.

When running with Igor Pro 6 on Macintosh an XOPMenuRef is a Macintosh Menu Manager MenuHandle. When running with Igor Pro 6 on Windows an XOPMenuRef is a handle created internally by Igor that emulates a Macintosh MenuHandle. When running with Igor Pro 7 an XOPMenuRef a pointer to an Igor C++ object. Each version of Igor handles XOPMenuRefs in its own way and you do not need to be concerned about the details.

Here is an example that illustrates the use of XOPMenuRefs:

```
XOPMenuRef menuRef;
menuRef = XOPResourceMenuIDToMenuRef(100);          // Get XOP's menu reference.
if (menuRef != NULL) {                              // Always test before using.
   XOPDisableItem(menuRef, 1);                      // Disable the first item.
   XOPSetMenuItemText(menuRef, 2, "Capture Image");// Set text of second item.
}
```

XOPResourceMenuIDToMenuRef is an XOPSupport routine and is described under **Getting Your Menu Reference** on page 153.

As shown you should always test a menu reference for NULL before using it. This will prevent a crash in the event of a bug in Igor or in your XOP or in the event of unforeseen changes in future versions of Igor.

Adding Menus and Menu Items

An XOP can add a main menu bar menu, any number of menu items to built-in Igor menus, and submenus to any menu items. Most XOPs will use it just to add a single menu item, if at all.

Here are the XOP resources that determine what an XOP adds:

Resource	What It Is Used For
XMN1 1100	Adds a menu to the main menu bar.
XSM1 1100	Adds submenus to XOP menu items.
XMI1 1100	Adds menu items to Igor menus.

The MenuXOP1 sample XOP illustrates the use of these resources which are described in detail below. See the MenuXOP1.r and MenuXOP1WinCustom.rc files in particular.

There are three limitations that you must be aware of.

First, the main menu bar can hold only a finite number of menus. It is possible for menus to be inaccessible because XOPs have added too many of them. You need to decide if your XOP should take space on the main menu bar or if it should merely add a submenu to a built-in Igor menu.

Second, there are 100 menu IDs reserved for all XOP main menus and 50 menu IDs reserved for all XOP submenus. It is unlikely that either of these limits will be reached but, since there are a limited number, you should use no more main menus or submenus than necessary in your XOP.

Finally, you must be careful when you create the resources in your XOP that describe your XOP's menus to Igor. It's not difficult to cause a crash by specifying the wrong menu IDs.

The following sections explain how Igor determines what menus, submenus and menu items your XOP adds.

Adding a Main Menu

Igor looks for an XMN1 1100 resource. XMN means "XOP menu". This resource specifies the menu or menus, if any that the XOP adds to the main menu bar.

Here is an example of an XMN1 resource:

```
// Macintosh
resource 'XMN1' (1100) {
   {
      100,              // menuResID: Menu resource ID is 100.
      1,                // menuFlags: Show menu when Igor is launched.
   }
};

// Windows
1100 XMN1
BEGIN
   100,                 // menuResID: Menu resource ID is 100.
   1,                   // menuFlags: Show menu when Igor is launched.
   0,                   // 0 required to terminate the resource.
END
```

The first field, called menuResID, is the resource ID of the MENU resource in the XOP's resource fork for the menu to be added to Igor's main menu bar.

The second field, called menuFlags, consists of bitwise flags defined in XOP.h as follows:

```
#define SHOW_MENU_AT_LAUNCH 1    // Bit 0
#define SHOW_MENU_WHEN_ACTIVE 2  // Bit 1
```

If bit 0 of the menuFlags field is set then the menu is appended to the main menu bar when Igor is launched. This is appropriate for a menu that is to be a permanent fixture on the menu bar. If bit 0 is cleared then the menu is *not* appended at this time.

If bit 1 of the menuFlags field is set then Igor automatically inserts the menu in the main menu bar when your XOP's window is active and removes it when your XOP's window is deactivated.

If neither bit is set then your XOP can show and hide the menu on its own using **XOPShowMainMenu** and **XOPHideMainMenu**. This is illustrated by the MenuXOP1 sample XOP.

The remaining bits are reserved and must be set to zero.

The resource shown adds one menu to Igor's main menu bar. To add additional menus you would add additional pairs of fields to the resource.

Adding Menu Items to Igor Menus

Igor looks for a resource of type XMI1 1100 that specifies menu items to be added to built-in Igor menus. XMI means "XOP menu item".

Here is an example of an XMI1 resource:

```
resource 'XMI1' (1100) {          // Macintosh, in MenuXOP1.r.
   {
      8,                          // menuID: Add item to menu with ID=8.
      "MenuXOP1 Misc1",           // itemText: This is text for added menu item.
      0,                        // subMenuResID: This item has no submenu.
      0,                        // itemFlags: Flags field.
   }
};

1100 XMI1                       // Windows, in MenuXOP1WinCustom.rc.
BEGIN
   8,                           // menuID: Add item to menu with ID=8.
   "MenuXOP1 Misc1\0",          // itemText: This is text for added menu item.
   0,                           // subMenuResID: This item has no submenu.
   0,                           // itemFlags: Flags field.
   0,                           // 0 required to terminate the resource.
END
```

The first field, called menuID, is the menu ID of the built-in Igor menu to which the menu item should be attached. The file IgorXOP.h gives the menu ID's of all Igor menus.

The second field, called itemText, is a string containing the text for the added menu item.

The third field, called subMenuResID, is the resource ID of the MENU resource in the XOP's resource fork for the submenu to be attached to the menu item or 0 for no submenu.

The fourth field, called itemFlags, consists of bitwise flags defined in XOP.h which tell Igor under what conditions the menu item should be enabled or disabled. See **Enabling and Disabling XOP Menu Items in Igor Menus** on page 154.

The resource shown adds one menu item to a built-in Igor menu. To add additional menu items you would add additional sets of fields to the resource. See MenuXOP1.r and MenuXOP1WinCustom.rc for examples.

Adding Submenus

Igor looks for a resource of type XSM1 1100. XSM means "XOP submenu". This resource specifies the submenu or submenus that the XOP wants to attach to menu items in menus that belong to the XOP, not built-in Igor menus.

Here is an example of an XSM1 resource:

```
resource 'XSM1' (1100) {   // Macintosh, in MenuXOP1.r.
   {
      101,           // subMenuResID: Add submenu with resource ID 101
      100,           // mainMenuResID: to menu with resource ID 100
      1,             // mainMenuItemNum: to item 1 of main menu
   }
};

1100 XSM1                   // Windows, in MenuXOP1WinCustom.rc.
BEGIN
   101,              // subMenuResID: Add submenu with resource ID 101
   100,              // mainMenuResID: to menu with resource ID 100
   1,                // mainMenuItemNum: to item 1 of menu
   0,                // 0 required to terminate the resource
END
```

The first field, called subMenuResID, is the resource ID of the MENU resource in the XOP's resource fork for the submenu to be attached to a menu item.

The second field, called mainMenuResID, is the resource ID of the MENU resource in the XOP's resource fork for the menu to which the submenu is to be attached.

The third field, called mainMenuItemNum, is the item number in that menu to which the submenu is to be attached.

The resource shown adds one submenu to an XOP menu. To add additional submenus you would add additional sets of fields to the resource.

mainMenuResID and mainMenuItemNum normally will refer to a menu declared in the XMN1 resource but can also refer to a menu declared in a previous record of the XSM1 resource. This allows submenus to have submenus.

Menu IDs Versus Resource IDs

On Macintosh only, when adding a MENU resource to your XOP, make sure that the menu ID and the resource ID are the same. The resource ID is used by the Macintosh Resource Manager but the Macintosh Menu Manager cares about the menu ID, not the resource ID. Here is a correct Rez resource description:

```
// From VDT.r
resource 'MENU' (100) {     // Resource ID is 100
   100,                     // Menu ID is same as resource ID
   textMenuProc,
   0xffffffff,
   enabled,
   "VDT",
   {
      . . .
   }
};
```

Responding to Menu Selections

When the user chooses an XOP’s menu item, Igor loads the XOP into memory, if it’s not already loaded, and sends a MENUITEM message to the XOP, passing it a menu ID and an item number that specify which item in which menu was chosen. The XOP responds by performing the appropriate action. It returns an error code to Igor, using the SetXOPResult XOPSupport routine, which indicates any problems encountered. If an error did occur, Igor presents a dialog with an appropriate error message.

Igor sends the MENUITEM message to Windows XOPs as well as to Macintosh XOPs. Windows XOPs will not receive a WM_COMMAND message from the Windows OS when the XOP's menu item is chosen.

How you interpret the menuID and itemNumber parameters that come with the MENUITEM message depends on how your XOP is set up.

Determining Which Menu Was Chosen

If your XOP adds just one menu item to Igor then matters are simple. When you receive the MENUITEM message, you know what the user chose without considering the menuID and itemNumber parameters.

Matters become more complex if your XOP adds more than one menu item. To understand this you need to know a bit about menu IDs. A menu ID is a number associated with a particular menu in a program.

In a standalone application, a menu ID for a given menu is normally the same as the resource ID for the resource from which the menu came. For example, Igor’s Misc menu has a menu ID of 8 and is defined by a MENU resource with resource ID=8 in Igor’s resource fork.

There could be several XOPs with MENU resources with ID=100 in their resource forks. Obviously, when all of these menus are loaded into memory, they can not all have menu IDs of 100. To get around this, Igor assigns new menu IDs to each XOP menu. This occurs when Igor inspects each XOP’s resources at the time Igor is launched.

The original resource ID of the XOP’s menu is called the “resource menu ID”. The ID assigned by Igor is called the “actual menu ID”.

When you write your XOP, you do not know the actual menu ID that your menu or menus will have when your XOP is running. Therefore, you need a way to translate between the actual menu ID and the resource menu ID. The XOP Toolkit provides two routines to handle this, **ResourceToActualMenuID** and **Actual-ToResourceMenuID**:

```
int
ResourceToActualMenuID(resourceMenuID)
int resourceMenuID;
```

Given the ID of a MENU resource in the XOP's resource fork, returns the actual menu ID of that resource in memory.

Returns 0 if XOP did not add this menu to Igor menu.

```
int
ActualToResourceMenuID(menuID)
int menuID;
```

Given the actual ID of a menu in memory, returns the resource ID of the MENU resource in the XOP's resource fork.

Returns 0 if XOP did not add this menu to Igor menu.

Imagine that your XOP adds one menu to Igor. When you get the MENUITEM message from Igor, you know that the menuID passed with that message is the actual menu ID for the XOP's menu so you don't need to use the ActualToResourceMenuID routine.

On the other hand, if your XOP adds two menus to Igor then, when you get the MENUITEM message, you do need to use the ActualToResourceMenuID routine to determine which of your two menus was selected.

In order to change your menu, for example, to disable one of its items, you need its menu reference. You can get the menu reference by calling XOPResourceMenuIDToMenuRef as described in the next section.

Getting Your Menu Reference

To actually do anything with your menu, such as enable or disable an item, you need to get a menu reference. The simplest way to do this is to call **XOPResourceMenuIDToMenuRef**. You pass it the resource menu ID for your menu and it returns the menu reference for the menu. This works for any menus that your XOP adds to Igor, including main menu bar menus and submenus.

It is also possible to use **XOPActualMenuIDToMenuRef** instead of XOPResourceMenuIDToMenuRef. You would first need to call **ResourceToActualMenuID** and then call XOPActualMenuIDToMenuRef. However there is no reason to do this. Use XOPResourceMenuIDToMenuRef instead.

When you obtain a menu reference you should always test it for NULL before using it. This will prevent a crash in the event of a bug in Igor or in your XOP or in the event of unforeseen changes in future versions of Igor.

Determining Which Menu Item Was Chosen

When your XOP adds an item to a built-in Igor menu, you always know the menu ID for the menu since it is defined in IgorXOP.h and is fixed for all time. However, since the menu item is appended to the end of the menu, you will not know the item's item number when you write the XOP. The **ResourceToActualItem** and **ActualToResourceItem** routines translate between resource item numbers and actual item numbers. Menu item numbers start from one.

```
int
ResourceToActualItem(igorMenuID, resourceItemNumber)
int igorMenuID;
int resourceItemNumber;
```

Given the ID of a built-in Igor menu and the one-based number of a menu item specification in the XMI1 resource in the XOP's resource fork, returns the actual item number of that item in the Igor menu.

Returns 0 if the XOP did not add this menu item to Igor menu.

```
int
ActualToResourceItem(igorMenuID, actualItemNumber)
int igorMenuID;
int actualItemNumber;
```

Given the ID of a built-in Igor menu and the actual number of a menu item in the Igor menu, returns the one-based number of the specification in the XMI1 resource in the XOP's resource fork for that item.

Returns 0 if the XOP did not add this menu item to Igor menu.

Enabling and Disabling Menu Items

When the user clicks in the menu bar or presses a keyboard equivalent, Igor allows all XOPs that are in memory to enable or disable menu items by sending the MENUENABLE message.

If an XOP window is the active window, Igor Pro disables all built-in menu items that pertain to the active window (e.g., Cut, Copy, Paste). It enables all menu items that can be invoked no matter what the active window is (e.g., Miscellaneous Settings, Kill Waves, Curve Fitting). Then it sends the MENUENABLE message to each loaded XOP that adds a menu or menu item to Igor. Igor sends the MENUENABLE message to the XOP that created the active window even if that XOP added no menu items. Each XOP can set its own menu items as it wishes. If its window is the active window, the XOP can also re-enable built-in Igor menu items that apply to the active window.

Igor sends the MENUENABLE message to Windows XOPs as well as to Macintosh XOPs. Windows XOPs will not receive a WM_INITMENU message from the Windows OS.

An XOP whose window is active can respond when the user selects a menu item. The menu item may be a built-in Igor menu item or it may be a custom item, created by the XOP. If the user selects a built-in Igor menu item and the XOP's window is the active window then Igor sends the XOP a menu-item-specific message. Examples are the kXOPWindowMessageCut, kXOPWindowMessageCopy, and kXOPWindowMessagePaste messages. If the user selects an XOP's custom menu item then Igor sends the MENUITEM message.

Since the XOP can respond to built-in and XOP menu items, it needs a way to enable and disable these items.

Enabling and Disabling XOP Menu Items in Igor Menus

When you receive the MENUENABLE message you can enable or disable menu items added to Igor menus by your XOP using the **XOPEnableMenuItem** or **XOPDisableMenuItem** menu routines. These routines require the menu reference for the menu, which you can obtain from **XOPActualMenuIDToMenuRef**.

There is another method which allows Igor to automatically enable and disable XOP menu items added to built-in Igor menus. This method involves the itemFlags field of the XMI1 1100 resource. The XOPTypes.r file defines the following bits for this field:

```
ITEM_REQUIRES_WAVES            ITEM_REQUIRES_GRAPH
ITEM_REQUIRES_TABLE            ITEM_REQUIRES_LAYOUT
ITEM_REQUIRES_GRAPH_OR_TABLE   ITEM_REQUIRES_TARGET
ITEM_REQUIRES_PANEL            ITEM_REQUIRES_NOTEBOOK
ITEM_REQUIRES_GRAPH_OR_PANEL   ITEM_REQUIRES_DRAW_WIN
ITEM_REQUIRES_PROC_WIN
```

For example, if you set the ITEM_REQUIRES_WAVES bit in the itemFlags field of your XMI1 1100 resource, Igor will automatically enable your item if one or more waves exists in the current data folder and automatically disable it if no waves exist in the current data folder.

For another example, if the ITEM_REQUIRES_GRAPH bit is set, Igor will enable your menu item only if the target window is a graph.

Enabling and Disabling Igor Menu Items

If your XOP adds a window to Igor, you might want to enable and disable Igor menu items such as Cut and Copy when your window is active. This section describes how to do this.

The **SetIgorMenuItem** XOPSupport routine allows the XOP to enable or disable a built-in Igor menu item without referring to specific menu IDs or item numbers. Here is a description:

```
int
SetIgorMenuItem(message, enable, text, param)
int message;            // an Igor message code
int enable;             // 1 to enable the menu item, 0 to disable it
char* text;             // pointer to a C string or NULL
int param;              // normally not used and should be 0
```

For example, if the user selects the Copy menu item, Igor sends the XOP the kXOPWindowMessageCopy message. If the XOP wants to enable the Copy menu item, it would call Igor as follows in response to the MENUENABLE message:

```
if (IsIgorWindowActive((xopWindowRef)) // Is XOP window active?
   SetIgorMenuItem(kXOPWindowMessageCopy, 1, NULL, 0);
```

The text parameter will normally be NULL. However, there are certain built-in Igor menus whose text can change. An example of this is the Undo item. An XOP which owns the active window can set the Undo item as follows:

```
if (IsIgorWindowActive((xopWindowRef)) // Is XOP window active?
   SetIgorMenuItem(kXOPWindowMessageUndo, 1, "Undo XOP-Specific Action", 0);
```

Call SetIgorMenuItem only if your XOP window is the active window.

Igor will ignore the text parameter for menu items whose text is fixed, for example Copy. For menu items whose text is variable, if the text parameter is not NULL, then Igor will set the text of the menu item to the specified text.

There is currently only one case in which the param parameter is used. If the message is FIND, Igor needs to know if you want to set Find, Find Same or Find Selected Text. It looks at the param parameter for this which should be 1, 2 or 3, respectively. In all other cases, you must pass 0 for the param parameter.

SetIgorMenuItem returns 1 if there is a menu item corresponding to message or 0 if not. Normally you will have no need for this return value.

Here is some code showing how to enable Igor menu items.

```
static void
XOPMenuEnable(void)
{
   .
   .
   if (IsIgorWindowActive((xopWindowRef)) { // Is XOP window active?
      SetIgorMenuItem(kXOPWindowMessageCopy, 1, NULL, 0);
      SetIgorMenuItem(kXOPWindowMessageCut, 1, NULL, 0);
   }
   .
   .
}
```

Chapter 9

Adding Windows

In Igor Pro 6 and before with XOP Toolkit 6 and before, it was possible for an XOP to add a window to Igor. This is no longer supported except for text utility windows described below.

Changes to operating systems, the Qt application framework on which Igor Pro 7 and later are built, and in Igor itself made it infeasible to support XOPs adding windows.

TU ("Text Utility") Windows

A TU window is a "text utility" window - a simple plain text editing window. The VDT2 sample XOP illustrate the use of a TU window. Most XOPs will not use text utility windows.

The Text Utility Window callbacks are documented in XOPSupport/XOPTextUtilityWindow.c, not in this manual.

If you are updating an old XOP, see “Changed Text Utility Window Callbacks” in Chapter 9 of the XOP Toolkit 7 manual for further information.

Chapter 10

Multithreading

Multithreading With XOPs

Multithreading allows a program to do more than one thing at a time. On a single-processor machine this works by giving a slice of time to each thread, giving the illusion of simultaneity. On a multiprocessor machine, multiple threads can execute at the same time on different processors, giving real simultaneity.

Multithreading is useful for two purposes:

- To allow a task to run without blocking other tasks

  For example, you can perform data acquisition in a thread while you analyze previously-acquired data in the main thread. The main thread will not block the data acquisition thread.
- To achieve greater throughput by utilizing multiple processors

  For example, you can run an analysis procedure on multiple data sets at one time using a thread for each data set.

Multithreading brings complications to programming. New rules must be followed to coordinate threads and keep them from interfering with one another. Programs that follow these rules are said to be "thread-safe".

Thread-safe programming is a vast topic which this manual will not cover except as it relates specifically to XOPs. We will assume that you understand the basics of thread-safe programming. If not, now would be a good time to familiarize yourself with it. A web search for “thread-safe programming” will get you started.

Multithreading is recommended only for experienced programmers. Whether you are experienced or not, you should verify that your XOP works correctly from the main thread before attempting multithreading.

Thread-safe External Operations and External Functions

For an external operation or function to be callable from a thread it must first be marked as thread-safe.

You mark an external operation as thread-safe using the XOPC resource that declares your operation and using the RegisterOperation callback that registers your operation with Igor. This is described under **Thread-Safe External Operations** on page 93.

You mark an external function as thread-safe using the XOPF resource that declares your function. This is described under **Thread-Safe External Functions** on page 117.

Once your external operation or external function is properly marked as thread-safe, Igor will allow you to call it from an Igor thread-safe user-defined function or to use it in a multithreaded computation (e.g., in a multithreaded curve fit). But marking it as thread-safe does not make it thread-safe - you must also write your operation or function in a thread-safe way. That is the subject of the following sections.

Three Kinds of Threads

We need to make a distinction between three kinds of threads:

- The main thread
- Igor preemptive threads
- Your own private internal preemptive threads that you create in your XOP

The *main thread* is created by the operating system when Igor is launched. Igor's outer loop and all user-interface activity run in the main thread. User-defined functions run in the main thread unless you explicitly create additional threads using Igor's ThreadGroupCreate and ThreadStart operations.

Igor preemptive threads are created by automatically multithreaded Igor operations like ImageInterpolate, when the MultiThread keyword is used to introduce a waveform assignment statement, and when an Igor user-defined function calls the ThreadGroupCreate operation.

You can use your own *private internal preemptive threads* in your XOP so long as Igor knows nothing about them. This means that you can not do a callback to Igor from one of your private internal threads.

NOTE: You can not do a callback to Igor from a private internal thread. You can do callbacks only from Igor's main thread and from Igor preemptive threads if the callback is designated as Igor-thread-safe.

Two Kinds of Igor Preemptive Threads

Igor preemptive threads can be classified as:

- Igor computation threads
- Igor user-defined function threads

An *Igor computation thread* is a thread created by an automatically multithreaded Igor operation such as ImageInterpolate or by a multithreaded waveform assignment statement using the MultiThread keyword.

An *Igor user-defined function thread* is created when a procedure calls the ThreadGroupCreate operation. The newly-created thread sleeps until you call the ThreadStart operation. ThreadStart starts a user-defined function, called a "worker function", running in an Igor preemptive thread created by ThreadGroupCreate.

The following sections focus on creating thread-safe external operations and functions to be called from Igor user-defined function threads but the considerations discussed also apply to Igor computation threads.

Igor Messages and Threads

Igor can call your XOP in three ways:

- Igor sends a message to your XOP by calling its XOPEntry routine from the main thread
- Igor calls your XOP's external operation from some thread
- Igor calls your XOP's direct external function from some thread

When we say that Igor sends a message to your XOP, we are speaking of the first of these three events. The mechanism by which Igor sends a message to an XOP is not thread-safe. Consequently, Igor will send a message to your XOP *from the main thread only*.

Writing Thread-safe Code

The topic of writing thread-safe code is vast and complex. In general, data that may be written by more than one thread, or written by one thread and read by another, requires special handling to prevent threads from interfering with each other. Your XOP's global variables are accessible by any thread and therefore create potential problems in a multithreaded environment. Globals that you set once at startup in the main thread and only read from preemptive threads are OK. Globals that you read and write from the main thread and/or preemptive threads are problematic.

If your external operation or function uses only data (waves, numbers, strings, structures) passed to it through parameters and its own local variables, and does not use any read/write global variables, then your code will be thread-safe and you don't need to know any more about it. For example, a curve fitting function typically takes a parameter wave and an X value as an input and computes a numeric result by simply doing number crunching on the parameters. Such a function is thread-safe.

On the other hand, an external operation or function that stores state information in global variables is not thread-safe. It can be made thread-safe using multithreaded programming techniques such as mutexes and semaphores. This is for advanced programmers only who have studied the details of thread-safe programming and even then is tricky. You can greatly simplify matters by eliminating global variables as much as possible. Eliminating them altogether is ideal.

Igor Preemptive Thread Data Environment

When Igor creates a new preemptive thread it also creates a new data hierarchy for use by that thread and that thread only.

This means that each Igor preemptive thread has its own root data folder possibly containing waves and variables and sub-data folders. This simplifies thread-safe programming because you can modify waves and Igor variables in your data hierarchy without worrying that other threads are also reading or writing them.

When you do a callback such as FetchWaveFromDataFolder, which returns a handle to a named wave in a specific data folder, you are looking for a wave in your thread's data hierarchy, not in the main Igor data hierarchy. When you call MDMakeWave, you are making a wave in your thread's data hierarchy, not in the main Igor data hierarchy. The same is true for Igor global variables.

Waves Passed to Igor Threads as Parameters

In addition to data in the Igor thread's data hierarchy, an Igor preemptive thread can also access waves from the data hierarchy of the calling Igor thread (typically the main thread) that are passed as parameters to the thread's worker function. In the case of an Igor user-defined function thread, the worker function is the function specified in the ThreadStart command.

For example, here is a thread worker function that passes a wave from the calling thread to an external operation:

```
ThreadSafe Function ThreadWorker(threadInputWave)
   Wave threadInputWave    // Lives in calling thread’s data hierarchy

   ExternalOperation threadInputWave
End
```

There are severe limits on what you are allowed to do with a thread parameter wave. It is the responsibility of the Igor user-function programmer to abide by these limits since the XOP programmer has no way to know if a given wave is a thread parameter wave.

Here is what you *can* do with a thread parameter wave:

- If the wave is numeric, you can read and/or write its data in the calling thread and in the receiving thread
- If the wave is text, you can read its data in the calling thread and in the receiving thread

If you write the wave’s data in both threads, the contents of the wave will be unpredictable so you should not do that.

If you read the wave's data in one thread while the other thread is writing it, you may read some spurious data. This would occur if the reading thread does a read while a write is partially complete. If you are just displaying the wave in a graph or table, a transitory spurious read is not fatal. However, if your application can not tolerate a transitory spurious read, you must make some arrangement to coordinate the reading and writing threads.

Here is what you *can not* do with a thread parameter wave:

- You can not redimension the wave or change other wave properties
- You can not kill the wave

Igor returns an error if you attempt these forbidden operations on a thread parameter wave.

In addition:

- If the wave is text, you can not write to it

Igor returns an error if you attempt to write to a thread parameter text wave using **MDSetTextWavePoint-Value**.

Igor returns an error if you attempt to write to a thread parameter text wave using **SetTextWaveData**.

The restrictions on a thread wave parameter end when the receiving thread's worker function returns.

Categories of XOPSupport Routines

XOPSupport routines can be categorized as either callback routines (e.g., **MDMakeWave**), which call back to Igor, and utility routines (e.g., **GetCStringFromHandle**), which do not call back to Igor.

In the following discussion, "callback routine" means an XOP Toolkit routine that calls back to Igor, "utility routine" means an XOP Toolkit routine that does not call back to Igor and "XOPSupport routine" means any XOP Toolkit routine (a callback or a utility).

Igor-Thread-Safe Callbacks

The thread-safety of each routine is listed in Chapter 15, **XOPSupport Routines**. Many of the routines are described as "Igor-thread-safe". This means that you can call them from Igor's main thread and from Igor preemptive threads. But you can not call such routines from your own private internal threads.

Thread-Safety of Callbacks from an Igor Preemptive Thread

Your XOP can do a callback to Igor from an Igor preemptive thread if the callback is designated as Igor-thread-safe. The documentation for each routine, in Chapter 15, **XOPSupport Routines**, tells you if the routine is Igor-thread-safe or not.

Not all XOPSupport routines are thread-safe. This is because some of the routines run code that is not written to be thread-safe. For example, the **XOPCommand** callback, which executes a command in Igor's command line, is not thread-safe.

Each XOPSupport routine that is not thread-safe checks to see if it is running in a thread other than the main thread. If so it:

- Displays a dialog alerting you to the fact that you are calling a thread-unsafe routine from a thread
- Returns a result that indicates that an error occurred, if the routine return value is not void

If this happens, your XOP has a bug that you need to correct.

Routines that return an error code return NOT_IN_THREADSAFE in this situation. Routines that return a handle, such as a wave handle or menu handle, return NULL.

It is important that you check the return value from every routine that returns a value and that you handle abnormal returns correctly. For example, if you inadvertently call a non-thread-safe routine from a thread and that routine normally returns a wave handle, it will return NULL. If you detect and deal with this correctly (e.g., by returning a NOWAV error to Igor), you will eventually get a reasonable error message. If you do not detect it, you will use the NULL handle and your XOP will crash. Debugging an error message is much easier than debugging a crash, so make sure to test and correctly handle all return values.

XOPSupport routines that deal with user interface - including menus, dialogs and windows - are not thread-safe.

In general, XOPSupport routines that read or write data folders, waves and variables are thread-safe.

You Can Not Do Callbacks From Private Threads

A private thread is a thread that your XOP creates as opposed to a thread that Igor creates. Only very advanced XOPs will need to use private threads.

You can not do any callbacks from private threads.

The rest of this section explains the reason for this restriction.

Each Igor thread has its own data hierarchy consisting of a root data folder, child data folders, and waves and variables stored in those data folders. Normally each thread accesses its own data hierarchy only. (The exception is that a thread can access waves passed to it as parameters from a another thread - see **Waves Passed to Igor Threads as Parameters** on page 161.)

This arrangement means that thread-safe user-defined functions, external operations and external functions do not need to worry about coordinating data access with other threads. They can access waves and variables in their own data hierarchy without the use of mutexes or other thread-safety techniques. This greatly simplifies Igor programming with threads.

Internally Igor maintains a data structure for each Igor thread that points to the thread's data hierarchy. To guarantee that a given thread accesses its data hierarchy only, Igor internally passes a pointer to this structure to any internal routine that needs to access data. For the purposes of this discussion, we will call this pointer an "Igor thread data pointer" or an ITDP for short. Just to be clear, an ITDP is a conceptual term for a pointer to a structure used internally by Igor to reference an Igor thread's data hierarchy.

When you do a callback from your XOP to Igor, Igor may need to access the current thread's data hierarchy and therefore needs an ITDP for the current thread. Igor obtains this from thread-local storage in which it stored the thread's ITDP when the thread was created. If you do a callback from an Igor thread, either the main thread or an Igor preemptive thread, Igor gets a valid ITDP from thread-local storage.

When you do a callback, Igor *assumes* that you are calling it from an *Igor* thread. If you do a callback from your *private* thread, Igor will attempt to get an ITDP and will get garbage. If the callback uses the ITDP, Igor will crash.

Another problem with doing callbacks from private threads is that there is no way to prevent a private thread and an Igor thread from changing Igor data (waves, variables and data folders) simultaneously.

Consequently, it is up to you to make sure that you refrain from doing callbacks to Igor from any private threads you create.

Determining if You are Running in a Preemptive Thread

Sometimes you might want to know if you are running in a preemptive thread so that you can do something one way if called from a thread or another way if called from the main thread. You can use the **RunningInMainThread** utility routine for this purpose.

If you have code that should never run in a preemptive thread, you can use **CheckRunningInMainThread** to inform yourself that, contrary to your expectations, it is being called from a thread:

```
   if (!CheckRunningInMainThread("SomeRoutineName"))
      return NOT_IN_THREADSAFE;
```

Replace “SomeRoutineName” with the name of your routine. This displays a dialog informing you of the error.

CheckRunningInMainThread should be used only to inform yourself that your thread-safety checks have failed to do the job and that code that is never supposed to execute from a thread is doing so. The XOP Toolkit uses it to inform you that you are calling a non-thread-safe XOPSupport routine from a thread.

If **CheckRunningInMainThread** returns 0 you know you are running in a preemptive thread but it does not tell you if you are running in an Igor preemptive thread or in your own private internal thread. If you use private threads, it is up to you to keep track of this distinction.

Strategies For Threaded Data Acquisition

In this section we assume that you want to acquire data in an Igor preemptive thread or in a private preemptive thread created by your XOP so that you can use Igor for other purposes while data is being acquired. This is recommended for experienced programmers only.

In order to display data in a graph or table or to pass it to non-thread-safe Igor operations, it needs to be in the data hierarchy of Igor’s main thread. There are four methods to achieve this. In two of the methods, the data is acquired in an Igor preemptive thread. In the other two, it is acquired in a private thread that your XOP creates. The first method has two variations:

Method	Data Acquired In	Data Acquired To	Data Transfer to Main Thread
Method 1A (page 165)	Igor Thread	Igor thread's data hierarchy	The Igor thread worker function, running in the preemptive thread, sends data to Igor’s thread output queue. An Igor named background task, running in the main thread, reads data from the thread output queue.
Method 1B (page 166)	Igor Thread	Igor thread's data hierarchy	The external operation or external function, running in the preemptive thread, sends data to Igor’s thread output queue. The XOP, running in the main thread, transfers data from the output queue to the main thread’s data hierarchy when Igor sends the IDLE message to the XOP or when an external operation or external function created for that purpose is called.
Method 2 (page 167)	Private Thread	XOP private data buffer	The XOP, running in the main thread, transfers data from its private buffer to the main thread's data hierarchy when Igor sends the IDLE message to the XOP or when an external operation or external function created for that purpose is called.
Method 3 (page 168)	Igor Thread	Main thread numeric waves	No transfer required
Method 4 (page 168)	Private Thread	Main thread numeric waves	No transfer required

The first two methods are clean but require more work on your part. The last two methods are quick and dirty. The last method is not recommended for XOPs that need to be bulletproof.

If you are comfortable creating your own threads and coordinating between threads then method 2 is preferred. Otherwise method 1A or 1B are preferred. Method 3 is the easiest to implement.

The following sections describe each of the methods. They assume that you are familiar with thread-safe programming in Igor itself. If not, you can come up to speed by:

- Reading the "ThreadSafe Functions and Multitasking" section of Igor's help. This is also available in the "Advanced Programming" chapter of the Igor Pro manual.
- Examining the "Slow Data Acq" example experiment. You can open it by choosing File→Example Experiments→Programming→Slow Data Acq.

The Slow Data Acq example experiment can be used as a starting point for your own Igor data acquisition project.

The following sections also assume that you have created an external operation to acquire data but an external function would also work.

Method 1A: Acquiring Data in an Igor Thread

In this variant of method 1, data is acquired in an Igor preemptive thread. It is transferred to Igor's thread output queue by the thread worker function. It is transferred from the thread output queue to the main thread's data hierarchy by a named background task.

Here is a schematic view of this method:

Igor Main Thread	Igor Preemptive Thread
A user-defined function creates a thread group (ThreadGroupCreate) and starts a thread worker function (ThreadStart)	
The user-defined function starts a named background task (CtrlNamedBackground) which periodically looks for data from the Igor preemptive thread (ThreadGroupGetDFR)	The thread worker function creates a data folder in the thread's private data hierarchy, sets it as the thread's current data folder, and calls the external operation
The user-defined function returns and the main thread is now free for interactive use	The external operation acquires data into the thread's current data folder, creating waves, variables and sub-data folders
	The external operation returns to the thread worker function
	The thread worker function sends data to the thread output queue (ThreadGroupPutDF)
The named background task receives data from the thread output queue and transfers it to the main thread (ThreadGroupGetDFR)	If more data is to be acquired, the thread worker function repeats the process
	The thread worker function returns and the Igor preemptive thread stops

Igor creates a separate data hierarchy for each Igor thread. This means that your thread worker function and your external operation can create data folders, waves and variables and can read and write waves without worrying about interference from other threads.

The tricky part is getting the data from the Igor preemptive thread into Igor's main thread so you can display it. That requires the participation of two threads: your preemptive thread and Igor's main thread.

Your thread worker function starts data acquisition by creating a data folder into which data will be acquired and then calling your external operation which runs until it has acquired the data. When your external operation returns, your thread worker function calls Igor's ThreadGroupPutDF operation to transfer the data folder to Igor's thread output queue. Your thread worker function can then call your external operation again or it can simply return if data acquisition is finished.

In the mean time, a user-defined function running in Igor's main thread calls ThreadGroupGetDFR to retrieve the data from Igor's thread output queue. To avoid monopolizing the main thread, this user-defined function must be a named background task. See "Background Tasks" in the Igor help or in the "Advanced Programming" chapter of the Igor manual for details.

After the data has been transferred, the background task function can process and/or display it by directly calling Igor operations or other user-defined functions.

The Slow Data Acq sample experiment simulates this entire process. It uses a user-defined function rather than an external operation to do the data acquisition. Carefully read the documentation and code included in that experiment. You can then use it as a starting point for your own XOP-based threaded data acquisition.

Method 1B: Acquiring Data in an Igor Thread

This variant of method 1 is the same as method 1A except that data is transferred to and from the Igor preemptive thread group's output queue by the XOP instead of by user-defined functions. This variant simplifies matters by eliminating the named background task, assuming there are not other reasons to use a background task.

In this variant of method 1, data is acquired in an Igor preemptive thread. It is transferred to Igor's thread output queue by the external operation running in the preemptive thread. It is transferred from the thread output queue to the main thread's data hierarchy by the external operation running in the main thread.

Here is a schematic view of this method:

Igor Main Thread	Igor Preemptive Thread
A user-defined function creates a thread group (ThreadGroupCreate) and starts a thread worker function (ThreadStart)	
The user-defined function returns and the main thread is now free for interactive use	The thread worker function calls the external operation to start data acquisition
	The external operation creates a data folder in the thread's private data hierarchy, sets it as the thread's current data folder, and acquires data into it, creating waves, variables and sub-data folders
	The external operation calls the **ThreadGroupPutDF** callback to transfer the data folder to the thread group's output queue
	The external operation returns to the thread worker function
Igor sends the IDLE message to the XOP	
The XOP calls **ThreadGroupGetDF** to see if data from the preemptive thread is available and to transfer it to the main thread's data hierarchy	If more data is to be acquired, the thread worker function repeats the process
	The thread worker function returns and the Igor preemptive thread stops

Igor creates a separate data hierarchy for each Igor thread. This means that your thread worker function and your external operation can create data folders, waves and variables and can read and write waves without worrying about interference from other threads.

The tricky part is getting the data from the Igor preemptive thread into Igor's main thread so you can display it. This requires the participation of two threads: your preemptive thread and Igor's main thread.

Your thread worker function calls your external operation to starts data acquisition. The external operation acquires the data, storing it in a data folder in the Igor thread's private data hierarchy. The external operation then calls the **ThreadGroupPutDF** callback to transfer the data folder to Igor's thread output queue.

In the mean time, Igor's sends IDLE message to your XOP from the main thread. Your XOP calls the **ThreadGroupGetDF** callback to transfer a data folder from Igor's thread output queue to the main thread's data hierarchy if one is available. Your XOP may then invoke Igor operations or a user-defined function via a callback such as **XOPCommand2** to display or further process the data.

Igor sends the IDLE message periodically when nothing else is going on - that is when no user-defined function or Igor operation is running in the main thread. You can force Igor to send an IDLE message to all XOPs by calling the DoXOPIdle operation from a user-defined function running in the main thread.

You can also create an external operation that causes your XOP to transfer data to the main thread, as if Igor had sent the IDLE message. You would call this external operation from the main thread only. This is more efficient than calling DoXOPIdle because DoXOPIdle sends IDLE messages to all XOPs.

Method 2: Acquiring Data in a Private Thread

In this method, data is acquired into your private buffer in a private thread that you create in your XOP. When your XOP receives an IDLE message from Igor, which occurs only in the main thread, it transfers data from the private buffer to Igor's main thread.

Here is a schematic view of this method:

Igor Main Thread	**XOP Private Thread**
A user-defined function calls an external operation to start data acquisition	
The external operation creates a private buffer into which data will be acquired and starts a private thread	The private thread acquires data into the private buffer
The user-defined function returns and the main thread is now free for interactive use	
Igor sends the IDLE message to the XOP	
If data is ready, the XOP transfers data from the private buffer to waves in the main thread	
If data acquisition is finished, the XOP stops the private thread	

Igor sends the IDLE message periodically when nothing else is going on - that is when no user-defined function or Igor operation is running in the main thread. You can force Igor to send an IDLE message to all XOPs by calling the DoXOPIdle operation from a user-defined function running in the main thread.

You can also create an external operation that causes your XOP to transfer data to the main thread, as if Igor had sent the IDLE message. You would call this external operation from the main thread only. This is more efficient than calling DoXOPIdle because DoXOPIdle sends IDLE messages to all XOPs.

Since your private buffer and any related control and status variables are shared by your private preemptive thread and your code running in the main thread, you need to use thread-safe programming techniques, such as mutexes, to coordinate thread activity.

Method 3: Acquiring Data in an Igor Thread Directly To Main Thread Waves

This method is simpler but has some significant limitations. You write an Igor user-defined function that creates a thread group and starts a thread worker function. You pass waves created in the main thread as parameters to your thread worker function. Your thread worker function calls your external operation which stores data in the waves.

Here is a schematic view of this method:

Igor Main Thread	**Igor Preemptive Thread**
A user-defined function creates waves to receive the acquired data	
The user-defined function creates a thread group (ThreadGroupCreate) and starts a thread worker function (ThreadStart), passing waves to the thread worker function	
The user-defined function returns and the main thread is now free for interactive use	The thread worker function calls the external operation, passing the waves as parameters
	The external operation acquires data into the waves and marks them as modified (WaveHandleModified)
	The external operation returns to the thread worker function
	The thread worker function returns and the Igor preemptive thread stops

Your thread worker function passes its parameter waves, which were created in the main thread, to your external operation. Your external operation stores data in the parameter waves and calls **WaveHandleModified** to tell Igor that the waves' data was changed. If the waves are displayed in a graph or table, Igor will update them in its main loop. You could call WaveHandleModified periodically to get periodic updates.

Waves passed as parameters from one thread to another are marked by Igor as in use by more than one thread and Igor returns an error if you attempt to change the waves, for example, by redimensioning them. However, you are allowed to change the data of numeric waves only. The restrictions on such waves are further discussed under **Waves Passed to Igor Threads as Parameters** on page 161.

The restrictions on a thread wave parameter end when the receiving thread terminates which is normally when the thread worker function returns.

Because you can not redimension thread parameter waves, you have to know how big to make them when data acquisition starts.

Method 4: Acquiring Data in a Private Thread Directly To Main Thread Waves

This method does not require any Igor preemptive threads but comes with even more restrictions than the preceding method. You call your external operation from Igor's main thread, passing waves to it as parameters. Your external operation obtains the addresses of the parameter waves' data by calling **WaveData** or **MDAccessNumericWaveData**. It then creates a private internal thread and passes the wave data addresses to it. Your external operation then returns, allowing Igor's main thread to continue. Your private internal thread writes directly to the waves using the technique described under **The Direct Access Method** on page 126.

Here is a schematic view of this method:

Igor Main Thread	XOP Private Thread
A user-defined function creates waves to receive the acquired data	
The user-defined function calls an external operation to start data acquisition, passing the waves to it	
The external operation starts a private thread and returns	The private thread acquires data into the waves
The user-defined function returns and the main thread is now free for interactive use	
The XOP receives IDLE messages from Igor and checks if data acquisition is finished	When data acquisition is finished, the private thread terminates
The XOP, detecting that data acquisition is finished, marks the waves as modified (WaveHandleModified)	

All of the restrictions discussed under **Waves Passed to Igor Threads as Parameters** on page 161 apply to this method. From a private thread, all you can do is read or write the data of numeric parameter waves. In addition, you can not do any callbacks to Igor from a private thread.

This last restriction means that you can not tell Igor that a wave is modified by calling **WaveHandleModified** from a private thread. You can do this when your XOP receives the IDLE message in the main thread or from an external operation running in the main thread. In order to know when to call WaveHandleModified, you will need to devise some coordination between your private thread and the main thread.

In addition, you must meet these requirements:

- To prevent a crash, the main thread must not kill, redimension or otherwise modify the parameter waves while the private thread is accessing them
- To prevent data corruption, the main thread must not write to the parameter waves while the private thread is accessing them
- To prevent a crash, if you receive the NEW or CLEANUP messages, signifying that waves are about to be killed, you must terminate your private threads

Because of the possibility of a crash, this method is not recommended for XOPs that must be bulletproof.

Finally, the caveats about spurious data in the preceding section apply to this method also.

Chapter 11

64-bit XOPs

Overview

XOP Toolkit 8 supports development of 64-bit XOPs for Macintosh and 32-bit and 64-bit XOPs for Windows. Starting withIgor Pro 8.00, 32-bit and 64-bit Igor versions are available on Windows but only the 64-bit version is available on Macintosh. XOP Toolkit 8 creates XOPs that require Igor Pro 8.00 or later.

We refer to the 64-bit version as IGOR64. The 32-bit version is called IGOR32.

IGOR32 can theoretically address up to 4 GB of virtual memory. In practice that actual limit is somewhere between 2 GB and 4 GB depending on your hardware, OS, and application. Most users will never come anywhere close to this limit.

IGOR64 allows you to access very large amounts of data at one time. IGOR64 can theoretically address 2^64 bytes of virtual memory, or roughly 17 billion GB. However, the operating system may impose further limits.

On Macintosh each process can theoretically access the full 17 billion GB. In 64-bit Windows operating systems, the limit depends on the operating system version as explained at:

```
http://msdn.microsoft.com/en-us/library/aa366778(VS.85).aspx
```

The maximum practical amount of data that you can access is determined by how much physical RAM you have in your system, your application, and how much patience you have. Even if you have plenty of physical RAM, processing gigabytes of data takes a long time.

Although most applications will never need the address space provided by IGOR64, 64-bits has become the defacto standard. Therefore we recommend that you use IGOR64. The only reason to use IGOR32 is if you use a Windows XOP that has not yet been ported to 32 bits.

IGOR32 can use 32-bit XOPs only. IGOR64 can use 64-bit XOPs only. It is not possible to run a 32-bit XOP with a 64-bit Igor or vice versa. Consequently, if you have a 32-bit XOP that you want to use with IGOR64 then you will have to port your XOP to 64 bits.

Instructions for adding a 64-bit target to an existing XOP project are available only in the XOP Toolkit 7 manual. If you are updating an XOP for which a 64-bit version was never created, update it using XOP Toolkit 7. See **Choosing Which XOP Toolkit to Use** on page 5 for details.

An alternate approach to updating a very old XOP to XOP Toolkit 8 is to create a new XOP from a sample XOP and then replace the sample source files with your source files. See **Alternate Method for Updating a Very Old XOP** on page 404 below for details.

IGOR64 loads only XOPs whose names end with "64" (e.g., WaveAccess64.xop). If your XOP's name ends with a digit (e.g., VDT2.xop), append "-64" (e.g., VDT2-64.xop).

IGOR32 loads only XOPs whose names do not end with "64" (e.g., WaveAccess.xop or VDT2.xop).

Activating a 64-bit XOP

You activate a 64-bit XOP by putting the XOP or a shortcut pointing to it in the “Igor Extensions (64-bit)” folder whch you can find in your “Igor Pro User Files” folder. See **Activating XOPs Using the Igor Extensions Folder** on page 6 for details.

Data Types For 64-bit Compatibility

When compiling a 64-bit executable, the long data type is 32 bits on Windows but 64 bits on Macintosh. Consequently the type long is problematic when compiling for 64 bits. Therefore in XOP Toolkit 6, all longs were changed to ints, if a signed 32 bit value was sufficient, or to the appropriate WaveMetrics data type.

Sometimes we need a value to be 32 bits when running a 32-bit XOP with IGOR32 but 64 bits when running a 64-bit XOP with IGOR64. Examples of such values are pointers, byte counts and wave point numbers.

In other cases we need a value to be the same size whether running in 32 or 64 bits. This is the case, for example, when reading or writing a field of a structure that is written to disk and read by both versions of an XOP.

The following data types are defined in XOPSupport/WMTypes.h which is #included as by XOPStandardHeaders.h. These data types are used to write code that works correctly with both 32-bit and 64-bit compilers on both Macintosh and Windows.

Types that are the same for 32-bit and 64-bit XOPs

These data types are the same in 32-bit and 64-bit XOPs.

Type	Description
SInt8	signed char (8 bits)
UInt8	unsigned char (8 bits)
SInt16	signed short (16 bits)
UInt16	unsigned char (16 bits)
SInt32	signed short (32 bits)
UInt32	unsigned char (32 bits)
TickCountInt	Tick count integer (32 bits) Used to hold a 32-bit unsigned tick count A tick is approximately 1/60th of a second
SInt64	signed 64-bit value
UInt64	unsigned 64-bit value

Types that are the different for 32-bit and 64-bit XOPs

These data types have different sizes in 32-bit and 64-bit XOPs.

Type	Description
PSInt	Pointer-sized integer 32 bits in 32-bit code, 64 bits in 64-bit code Used for integers that may hold pointers and for other situations where an integer should hold 32 bits in 32-bit code and 64 bits in 64-bit code
BCInt	Byte-count integer 32 bits in 32-bit code, 64 bits in 64-bit code Used to hold a byte count that needs to be 32 bits in 32-bit code and 64 bits in 64-bit code
IndexInt	Index integer 32 bits in 32-bit code, 64 bits in 64-bit code Used to hold a value used to index a pointer Also used to hold wave point numbers
CountInt	Count integer 32 bits in 32-bit code, 64 bits in 64-bit code Used to hold an item count that needs to be 32 bits in 32-bit code and 64 bits in 64-bit code such as the size of a wave dimension

Programming For 64-bit Compatibility

This section discusses some issues that you need to be aware of when writing a 64-bit compatible XOP.

Background Information

It is a good idea to familiarize yourself with 64-bit porting issues before writing 64-bit code.

Here is Microsoft's 64-bit porting guide:

```
http://msdn.microsoft.com/en-us/library/bb427430(VS.85).aspx
```

Here is Apple's 64-bit porting guide:

```
https://developer.apple.com/library/mac/documentation/Darwin/Conceptual/64bitPorting
```

64-bit Compiler Warnings

It is likely that you will get compiler warnings when compiling for 64 bits that you did not get when compiling for 32 bits. In many cases, you will need to use a cast to stop the compiler warning. For example, this line:

```
int len = strlen(name);
```

will give you a compiler warning because strlen returns a 64-bit integer and we are assigning it to a 32-bit variable. You can fix it with a cast:

```
int len = (int)strlen(name);
```

This cast is OK because we know that the length of the name string will fit in 32 bits.

Another example:

```
int len = WMGetHandleSize(waveH);
```

In this case, the value being stored in len could exceed 32 bits so this warning should be fixed like this:

```
BCInt len = WMGetHandleSize(waveH);
```

BCInt is a data type defined by the XOP Toolkit to hold byte counts. It is a 32-bit value when compiling for 32 bits and a 64-bit value when compiling for 64 bits. You could also use the standard C size_t data type.

If you know that the handle size can not exceed 32 bits then it is OK to store it in an int and to cast the result from WMGetHandleSize to an int:

```
int len = (int)WMGetHandleSize(fileNameH);
```

The long Data Type

On Windows in 64 bits, a long is a 32-bit integer as it was in 32 bits. However, on Macintosh and on Unix systems, a long is 64 bits. Because of this dichotomy, if you want to write cross-platform 64-bit code, you must get rid of longs in your code.

To deal with this and other issues, the XOP Toolkit provides portable data types in WMTypes.h. WMTypes.h is #included by XOPStandardHeaders.h. WMTypes.h defines SInt64 as a signed 64-bit integer regardless of platform. It also defines several other useful cross-platform data types - see **Data Types For 64-bit Compatibility** on page 172 for the complete list.

There are four situations with regard to longs:

- 32 bits is sufficient

  Example: A general purpose flag or count that will always fit in 32 bits

  Resolution: Change the long to an int
- 32 bits is always required

  Example: A field in a structure that must always be exactly 32 bits

  Resolution: Change the long to an SInt32
- 64 bits is always required

  Example: A field in a structure that must always be exactly 64 bits

  Resolution: Change the long to an SInt64
- 32 bits is required when running in 32 bits, 64 bits is required when running in 64 bits

  Example: A pointer or a count or index that can be arbitrarily large

  Resolution: Change the long to a BCInt, CountInt, IndexInt or PSInt

BCInt is used to store byte counts. CountInt is used to store other counts, such as the number of elements in a dimension of an Igor wave. IndexInt is used to store array indices including wave point numbers. PSInt (pointer-sized int) is used for integers that are used to store a pointer. These types are differentiated only to make the code better express the intent of the programmer.

Your job is to examine each long in your program and change it to the appropriate data type. We did this during the creation of IGOR64 and it resulted in thousands of changes. Fortunately most XOPs are much simpler and will require few changes.

Replacing longs in XOPEntry, RegisterFunction and SetXOPResult Calls

When Igor sends a message to your XOP, you often return a result using the **SetXOPResult** XOPSupport routine. In the case of the FUNCTION message, where Igor is asking for the address of your external function, the result is a pointer, specifically a pointer to your function. In many other cases the result is an int.

In IGOR32, pointers and ints are the same size but in IGOR64 pointers are 64 bits and ints are 32 bits. Consequently the data type returned to Igor via SetXOPResult had to be changed so that it is capable of holding a pointer. XOP Toolkit 6 introduced a type for this purpose: XOPIORecResult. XOPIORecResult is a typedef for SInt32 in IGOR32 and SInt64 in IGOR64.

If you are updating an old XOP, you must change your XOPEntry routine to return XOPIORecResult. For example, in the SimpleFit sample XOP we changed this:

```
extern "C" void
XOPEntry(void)
{
   long result = 0;

   switch (GetXOPMessage()) {
      case FUNCADDRS:
         result = RegisterFunction();
         break;
   }
   SetXOPResult(result);
}
```

to this:

```
extern "C" void
XOPEntry(void)
{
   XOPIORecResult result = 0;

   switch (GetXOPMessage()) {
      case FUNCADDRS:
         result = RegisterFunction();
         break;
   }
   SetXOPResult(result);
}
```

You must also change your RegisterFunction routine, if you have one, to return XOPIORecResult. For example, in the SimpleFit sample XOP we changed this:

```
static long
RegisterFunction()
{
   int funcIndex;

   funcIndex = GetXOPItem(0);
   switch (funcIndex) {
      case 0:
         return (long)SimpleFit;
         break;
   }
   return NULL;
}
```

to this:

```
static XOPIORecResult
RegisterFunction()
{
   int funcIndex;

   funcIndex = (int)GetXOPItem(0);
   switch (funcIndex) {
      case 0:
         return (XOPIORecResult)SimpleFit;
```

```
            break;
    }
    return 0;
}
```

GetXOPMessage and GetXOPItem Calls

Igor sends your XOP a message by calling your XOPEntry routine which calls **GetXOPMessage** to get the message. In XOP Toolkit 6, the result type of GetXOPMessage was changed from long to int. So, if you are porting an old XOP, you need to change your calls to GetXOPMessage routine from:

```
long message = GetXOPMessage();
```

to:

```
int message = GetXOPMessage();
```

When Igor sends you a message, you sometimes need to call **GetXOPItem** to get additional information. Sometimes the additional information is in the form of a pointer. Thus, the result type of GetXOPItem must be big enough to hold a pointer.

In XOP Toolkit 6, the result type of GetXOPItem was changed from long to XOPIORecParam. XOPIORecParam is defined as SInt32 in IGOR32 and SInt64 in IGOR64.

This does not cause a problem except that, when compiling for 64 bits, the compiler will issue a warning on a statement like this:

```
int funcIndex = GetXOPItem(0);
```

The warning will tell you that the 64-bit value returned by GetXOPItem is being stored in a 32-bit variable (funcIndex) which can possibly cause data truncation. In this case, you know that truncation is not an issue because a funcIndex is a small integer. To prevent the warning, you must change this code to:

```
int funcIndex = (int)GetXOPItem(0);
```

This tells the compiler that you know what you are doing when you assign a 64-bit value to a 32-bit variable.

If you already have a cast to another type, leave it as is. For example, this code from WindowXOP1 must not be changed:

```
XOP_WINDOW_REF windowRef;
windowRef = (XOP_WINDOW_REF)GetXOPItem(0);
```

printf and sprintf Issues

Functions in the printf family are problematic. They take a variable number of parameters and determine the type of the parameters using the first parameter which is a format string. If the type specified in the format string does not match the type of the actual parameter passed to the function, a crash can result.

When porting to 64 bits, you must examine every use of printf and sprintf and make sure that the format string and the actual parameters match. For example, suppose your old code looks like this:

```
long numPoints = WavePoints(waveH);
char buf[64];
sprintf(buf, "Number of points: %ld", numPoints);
```

Now, for 64-bit compatibility, you change it to:

```
IndexInt numPoints = WavePoints(waveH);
char buf[64];
sprintf(buf, "Number of points: %ld", numPoints);  // BUG
```

This creates a bug. The "%ld" format is correct when compiling as 32 bits because IndexInt is a typedef for long. But it is incorrect when compiling for 64 bits because IndexInt is a typedef for long long (a 64-bit signed integer). This kind of bug will produce incorrect results and can very easily cause a crash.

Here is one way to fix this so that it works on both 32 bits and 64 bits:

```
IndexInt numPoints = WavePoints(waveH);
char buf[64];
sprintf(buf, "Number of points: %lld", (SInt64)numPoints);
```

This technique insures that the value passed to sprintf is 64 bits whether you are compiling as 32 bits or 64 bits. It passes the correct format string, "%lld", to sprintf for a 64-bit integer value.

Be sure to inspect every call to printf and sprintf and make sure that they are correct for both 32 bits and 64 bit compilations.

Command Help for 64-bit XOPs

You provide command help (help for external operations and functions) by providing a suitably-named Igor help file.

Igor looks for a help file whose name is specified by your STR#,1101 resource in the same directory as the XOP.

If you don't have a STR#,1101 resource, Igor generates a default help file name based on the XOP name. For example, if your XOP is named MyXOP.xop or MyXOP64.xop, Igor would look for a file named "MyXOP Help.ihf". This is described under **Help for External Operations and Functions** on page 207.

If you have a 32-bit and a 64-bit version of an XOP, you need to provide only one help file. To support using just one help file, Igor makes several attempts to find the help file associated with the XOP.

Assume you have the following arrangement on your hard disk:

```
    MyXOP.xop
    MyXOP64.xop
    MyXOP Help.ihf
```

On Windows, Igor looks for the help file first in "Igor Extensions" and second in "Igor Extensions (64-bit)". Put MyXOP.xop and "MyXOP Help.ihf" in the "Igor Extensions" folder and MyXOP64.xop in the "Igor Extensions (64-bit)" folder. If you have no 32-bit version, put MyXOP64.xop and "MyXOP Help.ihf" in the "Igor Extensions (64-bit)" folder.

On Macintosh, as of Igor Pro 8.00, there is no 32-bit version of Igor and so there is no "Igor Extensions" folder. Put MyXOP64.xop and "MyXOP Help.ihf" in the "Igor Extensions (64-bit)" folder.

Other Programming Topics

The XOPMain Function

When Igor launches an XOP it calls the XOP's main function which is named XOPMain.

In ancient times, the main function of an XOP looked like this:

```
HOST_IMPORT int
main(IORecHandle ioRecHandle)
```

Modern compilers consider this form of main to be an error. All new XOPs and all XOPs that are being updated must use XOPMain:

```
HOST_IMPORT int
XOPMain(IORecHandle ioRecHandle)
```

WM Memory XOPSupport Routines

The WM memory XOPSupport routines provide a mechanism by which Igor and XOPs can exchange data in a compatible way.

WM memory XOPSupport routines use two data types: Ptr and Handle. They both provide access to a block of memory allocated in the heap. Ptr is rarely used while Handle is commonly used.

Handles are used by Igor to pass variable-length data to XOPs and to receive variable-length data from them. For example, Igor uses a Handle to pass a string parameter to an external function which returns a string result to Igor via a Handle.

The XOP Toolkit provides routines for dealing with Handles, such as WMNewHandle, WMGetHandleSize, and WMDisposeHandle. These routines evolved from the Macintosh Memory Manager which dates back to the 1980's. Igor and the XOP Toolkit still use Handles for backward compatibility.

Wave handles and data folder handles use different memory management techniques. Consequently the routines described in this section must not be used on wave handles or on data folder handles. Instead use the specific XOPSupport routines listed under **Routines for Accessing Waves** on page 240 and **Routines for Accessing Data Folders** on page 285.

For storing your own private data, you can use WM memory XOPSupport routines or standard C/C++ memory management routines. For data exchanged with Igor, you must use WM memory XOPSupport routines.

As explained under **Updating Old Code to Use WM Memory XOPSupport Routines** on page 182, 64-bit Macintosh XOPs created with XOP Toolkit 7.00 must be modified and recompiled to work with Igor Pro 8 and later on Macintosh.

Handle Example

Before we get into details, let’s start with a simple example using a Handle. This example sets the note property of a wave using the **SetWaveNote** callback routine.

```
int
DemoSetWaveNote()
{
   int err = 0;

   waveHndl waveH = FetchWave("wave0");
   if (waveH == NULL)
      return NOWAV;           // Wave does not exist

   char noteText[256];
   strcpy(noteText, "This is a test");
   int len = (int)strlen(noteText);

   Handle noteH = WMNewHandle(len);
   if (noteH == NULL)
      return NOMEM;

   err = PutCStringInHandle(noteH, noteText);
   if (err != 0) {
      WMDisposeHandle(noteH);
      return err;
   }

   err = SetWaveNote(waveH, noteH);    // Igor now owns the noteH Handle

   return err;
}
```

This routine uses WMNewHandle to create a Handle, PutCStringInHandle to set the contents of the Handle, and WMDisposeHandle to free the handle.

The next section explains why the XOP does not dispose noteH after passing it to SetWaveNote.

Ownership of Handles

When a Handle is passed between Igor and an XOP, in some cases the caller retains ownership of the handle and is responsible for disposing it. In other cases, the callee takes ownership of the handle and is responsible for disposing it. In the preceding example, once the call to **SetWaveNote** is made, Igor owns the handle so the XOP does not dispose it. The XOP Toolkit documentation for each XOPSupport routine that uses a Handle states the ownership rules for that routine.

Commonly-Used WM Memory XOPSupport Routines

This table lists the WM memory XOPSupport routines that are commonly used in XOP programming. These routines, as well as some less commonly used routines, are described in detail in the section **WM Memory Routines** on page 391.

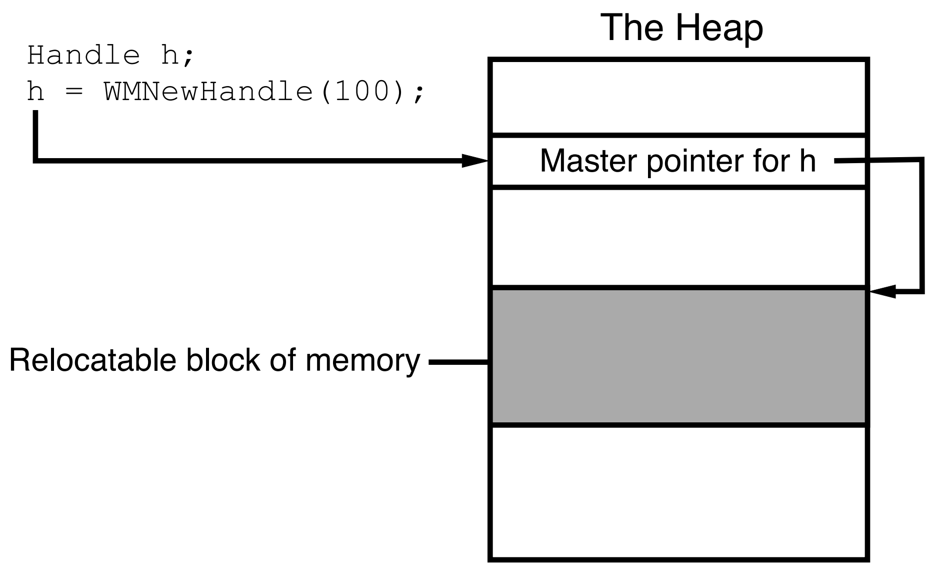
Routine	What It Does
Handle **WMNewHandle**(BCInt size);	Allocates a block of memory in the heap and returns a handle to it.
BCInt **WMGetHandleSize**(Handle h);	Returns the number of bytes in the block of memory referred to by the handle.

Routine	What It Does
void **WMSetHandleSize**(Handle h, BCInt size);	Sets the number of bytes in the block of memory referred to by the handle.
void **WMDisposeHandle**(Handle h);	Frees the block of memory pointed to by the handle.

Understanding Handles

The WMNewHandle function allocates a block of memory on the heap and returns a Handle which references that block. Unlike a pointer, which points directly to a block of memory, a Handle points indirectly to the allocated memory block.

Specifically, a Handle points to a pointer to the block. The handle contains the address of a master pointer which contains the address of the block of memory in the heap. This illustration shows the relationship of a Handle and the block of memory that it refers to:



Because a handle refers to a block of memory indirectly, you must "dereference" the handle before you can access the block. For example, if h is a handle returned by WMNewHandle, then *h is a pointer to the block of memory that h refers to.

In this example, we call WMNewHandle to allocate a two-byte block of memory. We set the first byte to 0 and the second byte to 1. We then dispose the Handle.

```
Handle h = WMNewHandle(2);
if (h == NULL)
   return NOMEM;
char* p = (char*)*h;       // DEREFERENCE
*p = 0;
*(p+1) = 1;
WMDisposeHandle(h);
```

Handles were invented for the original Macintosh OS to provide a way for the operating system to defragment memory in a heap shared by all applications. The OS would move relocatable blocks if needed to satisfy a new memory allocation request. There were two situations in which the block of memory for a given handle could be moved:

- To compact memory so that another block of memory could be allocated or resized
- To find room to increase the size of the given handle’s block when it is resized

The block of memory referenced by a Handle is no longer relocated to compact memory but it still can be relocated when that handle's block is resized to a larger size.

Using Handles

In the snippet above, once h is dereferenced, p points to the block of memory in the heap. In the original Macintosh OS, the OS could relocate the block of memory to satisfy an allocation request for a different handle or pointer, leaving p pointing to the previous location of the block. In this event p was said to be a "dangling pointer".

Writing to memory referenced by a dangling pointer is a disaster. It creates intermittent bugs that sometimes cause crashes well after the bad write. Finding the cause of such a bug is very difficult and time-consuming.

The problem of dangling pointers is greatly reduced because, unlike in times of old, blocks of memory are no longer relocated to satisfy memory allocation requests involving other blocks.

Resizing Handles

The problem of dangling pointers is not completely gone. If you increase the size of a handle by calling WMSetHandleSize, it may not be possible to increase the size of the referenced heap block in place. This occurs if the memory following the heap block is in use. In this situation, WMSetHandleSize relocates the heap block and adjusts the handle's master pointer accordingly. This means that, any time you increase the size of a handle, you must re-dereference it.

You also need to re-dereference a handle if you decrease its size. WMSetHandleSize ultimately calls the C realloc function or its equivalent. realloc can relocate a block of memory any time it is called. Although it is relatively rare, some implementations may relocate memory when a block's size is decreased to reduce memory fragmentation.

NOTE: Any time you increase or decrease the size of a handle, you must re-dereference it.

For example:

```
int err = 0;

Handle h = WMNewHandle(2);
if (h == NULL)
   return NOMEM;
char* p = (char*)*h;          // DEREFERENCE
*p = 0;
*(p+1) = 1;

err = WMSetHandleSize(h,4);   // Increase size of handle
if (err == 0) {               // Make sure resize succeeded
   p = *h;                    // RE-DEREFERENCE
   *(p+2) = 2;
   *(p+3) = 3;
}

WMDisposeHandle(h);
return err;
```

For further discussion of this issue, see **Dangling Pointers** on page 216.

Updating Old Code to Use WM Memory XOPSupport Routines

This section explains a compatibility issue that affects Macintosh 64-bit XOPs running with Igor Pro 8 or later. The bottom line is:

- 64-bit Macintosh XOPs created with XOP Toolkit 7.00 must be modified and recompiled with XOP Toolkit 7.01 or later to run with Igor Pro 8

- 32-bit and 64-bit Windows XOPs do not need to be modified, but we recommend that you modify them when you next update such XOPs

Details of the required modifications are provided below. First, here is background information to help you understand the issue.

Historically on Macintosh, Igor and XOPs always used native Macintosh Handles and consequently used native Mac OS routines such as NewHandle, GetHandleSize, SetHandleSize, and DisposeHandle. On Windows, they always used WaveMetrics emulation routines with the same names, implemented in Igor and exported to XOPs through the IGOR.lib and IGOR64.lib files.

Native Macintosh Handles are limited by Mac OS to roughly 2 GB. This is unfortunately true even when running a 64-bit application. WaveMetrics emulation of Macintosh Handles never had this limitation.

Igor Pro 7 was the first version of Igor that ran in 64 bits on Macintosh and XOP Toolkit 7.00 was the first version of the XOP Toolkit that supported compilation of 64-bit Macintosh XOPs.

Working with the 64-bit Macintosh version of Igor Pro 7 over time, we noticed that the Mac OS 2 GB limitation sometimes caused problems. To overcome this limit, starting with Igor Pro 8, the Macintosh 64-bit version of Igor also uses emulation of Handles. This table summarizes Igor's use of Handles:

	Igor Pro 7 and before	**Igor Pro 8 and later**
Macintosh 32 Bit	Native Macintosh	Native Macintosh
Macintosh 64 Bit	Native Macintosh	WaveMetrics Emulation
Windows 32 Bit	WaveMetrics Emulation	WaveMetrics Emulation
Windows 64 Bit	WaveMetrics Emulation	WaveMetrics Emulation

As the table shows, the only change is that, as of Igor Pro 8, Igor uses its own emulation of Handles instead of Mac OS native Handles when running on Macintosh in 64 bits.

For Handles passed between Igor and XOPs, such as for string parameters and string result, Igor and XOPs must use the same implementation of Handles. For example, if Igor allocates such a Handle to pass a parameter to an XOP, the XOP needs to call a function to determine the number of bytes associated with the Handle. The Mac OS native GetHandleSize function works only with Handles allocated by the Mac OS native NewHandle function. It does not work with Handles allocated by WaveMetrics' emulation of NewHandle. The converse is also true. So, when it comes to Handles, Igor and XOPs must use the same set of functions. Either both must use native Mac OS functions or both must use WaveMetrics emulation functions.

To make this possible, in XOP Toolkit 7.01, we introduced new routines named WMNewHandle, WMGetHandleSize, and so on. XOPs that use these WaveMetrics routines call the correct functions regardless of Igor version and operating system. See **WM Memory XOPSupport Routines** on page 179 for background information.

Because of the change to Handles in the 64-bit Macintosh version of Igor Pro 8, when running in 64 bits on Macintosh, Igor Pro 8 and later report an error if you attempt to load an XOP created with XOP Toolkit 7.00. You must modify such XOPs to use WaveMetrics memory XOPSupport routines instead of Mac OS native routines and recompile them using XOP Toolkit 7.01 or later. Existing Windows 32-bit and 64-bit XOPs continue to work as before.

Windows-only XOPs can be compiled without changes in XOP Toolkit 7.01 or later. However, for consistency we recommend that you update even Windows-only XOPs.

To update your XOP to use WM memory XOPSupport routines, follow these steps:

1. Replace all NewHandle calls with WMNewHandle.
2. Replace all GetHandleSize calls with WMGetHandleSize.

3. Replace all SetHandleSize calls with WMSetHandleSize.
4. Replace all HandToHand calls with WMHandToHand.
5. Replace all HandAndHand calls with WMHandAndHand.
6. Replace all DisposeHandle calls with WMDisposeHandle.
7. Replace all NewPtr calls with WMNewPtr.
8. Replace all GetPtrSize calls with WMGetPtrSize.
9. Replace all SetPtrSize calls with WMSetPtrSize.
10. Replace all PtrToHand calls with WMPtrToHand.
11. Replace all PtrAndHand calls with WMPtrAndHand.
12. Replace all DisposePtr calls with WMDisposePtr.
13. Remove all calls to MemError (details below).
14. Recompile your XOP.

Most XOPs call only a few of these routines so the number of changes required will typically be small.

Check your changes carefully. If you fail to replace, for example, NewHandle with WMNewHandle, you will get a link error when you build on Macintosh. The error occurs because of #defines in XOPMacSupport.h designed to make you aware if you forget to replace a Mac OS native call with the corresponding WM memory XOPSupport routine call.

There are some differences between the WM memory XOPSupport routines and the corresponding Macintosh routines:

1. WMSetHandleSize and WMSetPtrSize return an error code while the corresponding native Macintosh routines do not.
2. There is no WMMemError function corresponding to the native Macintosh MemError function. If you have a call to MemError, replace it like this:

Old	**New**

`SetHandleSize(h, newSize);`
`err = MemError();`
	`err = WMSetHandleSize(h, newSize);`

3. WMDisposeHandle and WMDisposePtr do nothing if passed a NULL parameter while the corresponding native Macintosh routines treat this as an error (nilHandleErr) which MemError returns.

It is unlikely that you call any native Mac OS routines that return Handles. However if you do, you must treat such native Mac OS Handles differently. You must use native Mac OS functions, not WaveMetrics memory XOPSupport routines, on native Mac OS Handles. In this case, you must #define ALLOW_MAC_OS_NATIVE_MEMORY_ROUTINES as otherwise the #defines in XOPWinMacSupport.h will prevent you from using native Mac OS functions.

If you find it necessary to define ALLOW_MAC_OS_NATIVE_MEMORY_ROUTINES, be very careful. If you pass a Mac OS native Handle to Igor, or if you pass a WM handle to Mac OS, you are likely to corrupt memory, causing a crash that is very hard to track down.

Techniques for Cross-Platform Development

It is best to maintain one set of source code for both the Macintosh and Windows versions of your XOP. Much of the source code, such as routines for number crunching or interfacing with Igor, will be completely platform-independent. Menu-related and file-related routines can also be platform-independent because of the support provided by the XOPSupport library.

Most XOPs can be written in a mostly platform-independent way. The MenuXOP1, NIGPIB2, SimpleFit, SimpleLoadWave, WaveAccess, XFUNC1, XFUNC2, XFUNC3, XOP1, and XOP2 sample XOPs have no platform-specific C source files and few platform-related ifdefs. Routines for number crunching or interfacing with Igor are inherently platform-independent.

XOPs that add dialogs, such as GBLoadWaveX, require platform-specific files. See **Adding Dialogs** on page 192 for details.

Text Encodings

A text encoding is a mapping from a set of numbers to a set of characters. For example, in the ASCII text encoding the number 0x41 (decimal 65) maps to the character Upper Case Letter A. The text encodings that are commonly used with Igor Pro 6 are MacRoman, Windows-1252 (also called "Western") and Shift JIS (Japanese). Igor Pro 7 and later use UTF-8. For further background information, execute this in Igor Pro 7 or later:

```
DisplayHelpTopic "Text Encodings"
```

In Igor Pro 6 and earlier, Igor used the "system text encoding" to represent text.

On Macintosh you set the system text encoding by setting the preferred language in the Languages&Region control panel. For most Macintosh Igor users the system text encoding is MacRoman or Shift JIS.

On Windows the system text encoding is called the "system locale" or "language for non-Unicode programs". You set it in the Administrative tab of the Region control panel. For most Windows Igor users the system text encoding is Windows-1252 or Shift JIS.

Starting with Igor Pro 7, Igor uses Unicode instead of the system text encoding. Specifically Igor Pro 7 uses UTF-8 — a Unicode encoding form that represents a given character using one, two, three or four bytes. Unicode allows you to access any character, rather than a limited set, and works the same on Macintosh, Windows, and any other platform.

Like most text encodings, UTF-8 uses the same one-byte codes as ASCII to represent the ASCII characters (represented by codes from 0x00 to 0x7F). Consequently, if you use ASCII characters only, you do not need to be concerned with text encoding issues. Non-ASCII characters, including accented characters, special symbols, Greek letters, and Asian characters, are represented using two, three or four bytes and are different in UTF-8 than in other text encodings.

Except as otherwise specified in the documentation for a given Igor message or XOPSupport routine, all string parameters are assumed to be encoded as UTF-8 when running with Igor Pro 7 or later.

In most cases text that you pass to an XOPSupport routine originates in Igor and therefore uses the appropriate text encoding for the Igor version that you are running, so you don't need to worry about text encodings. However if the text that you pass to an XOPSupport routine does not originate in Igor then you must make sure that it uses the right text encoding for the version of Igor that you are running.

One example of text that does originate in Igor is literal text in your program, such as a string that you might print in Igor's history area using the XOPNotice callback. This is discussed below under **Text Encodings in Source Files** on page 186.

For another example, if you are running with Igor Pro 7 or later, and you read text from a file containing non-ASCII characters encoded as Windows-1252, and you store that text in an Igor text wave (using a callback such as **MDSetTextWavePointValue**), you must convert from Windows-1252 to UTF-8 and pass the UTF-8 text to the callback. Otherwise you will store text in the wave that is not valid UTF-8 text for the non-ASCII characters. This will lead to incorrectly rendered text later when the user displays the text and may cause errors when manipulating it. You can use the **ConvertTextEncoding** callback to do the conversion.

Since ASCII text (codes from 0x00 to 0x7F) is the same in nearly all text encodings that might be used on personal computers, text encoding is an issue only for non-ASCII text such as accented characters, special symbols, Greek letters, and Asian characters.

In the MDSetTextWavePointValue example, if you know that the file contains only ASCII text then you don't need to do any conversion because UTF-8 uses the same codes as ASCII for ASCII characters. However if the file might contain non-ASCII text, such as accented characters, if you fail to convert to UTF-8 you will store a byte sequence in the Igor text wave that is illegal in UTF-8. This will cause incorrect rendering or errors later.

Here are XOPSupport routines that relate to text encoding issues. They all require Igor Pro 7.00 or later:

Routine	Description
ConvertTextEncoding	Converts text from one text encoding to another.
WaveTextEncoding	Returns the text encoding code for an element of a wave. Most XOPs will not need to use this routine.

Igor Pro Text Encoding Codes

The routines listed above use Igor-specific codes to represent text encodings. These codes are defined by the WMTextEncodingCode enum which is defined in IgorXOP.h. The codes most commonly used with Igor are:

WMTextEncodingCode Enum	Description
kWMTextEncodingUTF8	UTF-8.
kWMTextEncodingMacRoman	Used for western text on Macintosh.
kWMTextEncodingWindows1252	Used for western text on Windows.
kWMTextEncodingJIS	Shift JIS, used for Japanese text.
kWMTextEncodingBinary	This is not a real text encoding. Rather it is used to mark the text data of a text wave that really contains binary data.

Text Encodings in Source Files

The material in this section is relevant if your XOP uses non-ASCII text.

XOP Toolkit projects are configured to use UTF-8 text encoding so that programmers can enter literal strings using any character in a cross-platform manner. If you enter a literal string containing non-ASCII text in a source file configured as UTF-8, it will be correct for use with Igor Pro 7 or later. For example:

```
XOPNotice("This is a bullet character: •" CR_STR);
```

This will produce the correct bullet character with Igor Pro 7 or later on all platforms.

You should use UTF-8 text encoding for all C/C++ source files.

Do not use non-ASCII text in resource files (.r on Macintosh, .rc on Windows) as resource compilers have no or limited support for UTF-8.

In XOP Toolkit 7, we added UTF-8 byte-order marks (BOMs) to all of the C/C++ source files shipped with the XOP Toolkit. This had no effect in Xcode but guaranteed that Visual Studio would recognize the files as UTF-8. However, whereas Visual Studio preserves the UTF-8 BOM when you edit a file, Xcode removes it. Consequently some of the source files shipped with the XOP Toolkit lost their BOMs. For XOP Toolkit 8.02, we decided to remove the BOMs altogether.

Text Encodings in Xcode

In Xcode you can use the File Inspector text encoding setting to set the text encoding for a given source file to MacRoman, UTF-8 or any other text encoding. This per-file setting is stored in the project file. Consequently, it sticks if you share the project file with another programmer.

Xcode does not automatically set the text encoding of a file based on its contents, even if the file contains UTF-8 text, and even if the file starts with a UTF-8 byte order mark. It always treats the file using the encoding stored for the file in the project, as set by the Text Encoding popup menu in the File Inspector pane.

The XOP Toolkit Xcode projects are configured to use UTF-8 for source files except for resource files (.r files and XOPResources.h). Resource files are configured as MacRoman because the Rez resource compiler used by Xcode does not support UTF-8 so we recommend not using non-ASCII text in resource files.

The sample XOP projects use CRLF line endings in C/C++ files for compatibility with Windows editors. To preserve the CRLF line endings if you edit files in Xcode, set Xcode's "Default Line Endings" preference to "Windows (CRLF)".

Text Encodings in Visual C++

In Visual Studio 2015, 2017 and 2019, you can set the text encoding for a given file by opening the file, choosing File→Save As, clicking the triangle next to the Save button, and choosing Save With Encoding. This displays the Advanced Save Options dialog. Once you choose the desired text encoding, you can proceed to finish the Save As operation.

The text encoding setting, as set in the Advanced Save Options dialog, is not saved in the project but merely remembered while the file is open in the editor pane. If you close and reopen the file, or close and reopen the project, the text encoding setting for the file reverts to the default system text encoding, usually Windows-1252, unless Visual Studio recognizes it as containing UTF-8 characters in which case it is treated as UTF-8.

If you set the file text encoding to "UTF-8 with signature", Visual Studio adds a UTF-8 byte order mark to the file. ("signature" is Microsoft terminology for "byte order mark".) If you then save the file, close it and reopen it, Visual Studio recognizes the UTF-8 byte order mark and treats the file as UTF-8.

Because some text editors, such as Xcode, do not preserve byte order marks, it is difficult to guarantee that files retain them. Consequently, as of XOP Toolkit 8.02, we no longer ship C/C++ files with byte order marks and instead rely on Visual Studio recognizing UTF-8 non-ASCII characters.

Resource files (.rc and resource.h) are configured as Windows-1252 because the Windows resource compiler does not support UTF-8.

In addition to making the Visual Studio editor use UTF-8, we need to make the Visual C++ compiler use it. To do that, we include the /utf-8 flag in the Command Line section of the C/C++ section of the property pages for all configurations of the project. The /utf-8 flag is discussed at https://msdn.microsoft.com/en-us/library/mt708821.aspx. As explained at support.microsoft.com/en-us/kb/980263, this setting requires Visual Studio 2015 Update 2 or later. The /utf-8 flag affects the compiler only - it does not force the editor to treat the file as UTF-8.

File I/O

The XOP Toolkit provides the following platform-independent routines for creating, deleting, reading, writing, and otherwise dealing with files:

FullPathPointsToFile	**FullPathPointsToFolder**	
XOPCreateFile	**XOPDeleteFile**	
XOPOpenFile	**XOPCloseFile**	
XOPReadFile	**XOPReadFile2**	**XOPReadLine**
XOPWriteFile		
XOPGetFilePosition	**XOPGetFilePosition2**	
XOPSetFilePosition	**XOPSetFilePosition2**	

XOPNumberOfBytesInFile **XOPNumberOfBytesInFile2**

XOPAtEndOfFile

These routines are defined in XOPFiles.c, XOPFilesMac.c and XOPFilesWin.c. Some of them (e.g., XOPOpenFile) use full paths to identify files. The full paths must be “native”. That is, on Macintosh, they must be HFS paths using colons as path separators and on Windows they must use backslashes. Do not use POSIX paths (with forward slashes).

File name and path parameters that you pass to these routines must be encoded as UTF-8. If the file name or path is ASCII then this requirement is satisfied. Otherwise, if you receive the file name or path from Igor as a parameter to an external function or operation then this requirement is satisfied.

The XOP Toolkit provides symbols to use when allocating buffers for volume names, folder names, file names and paths. For example:

```
char volumeName[MAX_VOLUMENAME_LEN+1];
char volumeName[MAX_DIRNAME_LEN+1];
char volumeName[MAX_FILENAME_LEN+1];
char volumeName[MAX_PATH_LEN+1];
```

These statements allocate the appropriate size buffers on all platforms. The "+1" adds room for the null terminator. The MAX_ symbols shown above are defined in IgorXOP.h.

The XOP Toolkit also provides the **XOPOpenFileDialog2** and **XOPSaveFileDialog2** routines which allow the user to choose a file to open or to specify where to save a file. Other XOPSupport routines provide the means to obtain a full path to a file based on parameters from a command-line command. The file-loader XOPs SimpleLoadWave and GBLoadWaveX illustrate the use of these routines.

If your XOP uses the old **XOPOpenFileDialog** and **XOPSaveFileDialog** routines, we recommend that you modify them to use the newer **XOPOpenFileDialog2** and **XOPSaveFileDialog2** routines.

File Path Conversions

The Macintosh and Windows operating systems use different syntax for creating a path to a file. Here are some examples.

Macintosh	Windows	Path Type
hd:Folder1:Folder2:File	C:\Folder1\Folder2\File	Full path
:Folder2:File	.\Folder2\File	Partial path

On MacOS, POSIX paths with forward slashes are often used. However, Igor and the XOP Toolkit, for historical reasons, use Macintosh HFS (hierarchical file system) paths with colon separators. When we speak of “Macintosh paths”, we are talking about HFS colon-separated paths.

Igor commands can refer to files using paths. HFS paths are recommended but Windows paths are also accepted. So that an Igor programmer can write procedures that work on any platform, commands must work regardless of which platform they are executing on. For example, the commands:

```
LoadWave/J/P=Igor ":Examples:Programming:AutoGraph Data:Data0"
LoadWave/J/P=Igor ".\\Examples\\Programming\\AutoGraph Data\\Data0"
```

must work on both Macintosh and Windows. (Note that in a literal string in an Igor command, you must use "\\" to represent a single backslash because backslash is an escape character in Igor.)

This requirement means that an XOP that deals with a file path must accept the path in either Macintosh HFS or Windows format. The technique used by the sample XOPs is to convert all paths to the native format as soon as the path is received from the command. "Native" means that the path uses Macintosh HFS syntax when running on Macintosh and Windows syntax when running on Windows. For example, SimpleLoad-WaveOperation.cpp calls the GetNativePath routine to convert its input parameter.

GetNativePath is an XOPSupport routine that converts a path to the conventions of the platform on which the XOP is running. On Macintosh, it converts to Macintosh HFS conventions and on Windows, it converts to Windows conventions. If the path already uses the correct conventions, GetNativePath does nothing. GetNativePath calls other XOPSupport routines, **MacToWinPath** and **WinToMacPath**. If you use the technique of converting all paths to native format as soon as possible, then you will not need to use MacToWinPath and WinToMacPath directly but can use just GetNativePath.

Other cross-platform path-related XOPSupport routines include **ConcatenatePaths**, **GetDirectoryAndFileNameFromFullPath**, **FullPathPointsToFile**, and **FullPathPointsToFolder**.

On MacOS you may need to convert an HFS path that you receive as a parameter to a POSIX path in order to call an operating system routine or a standard file library I/O routine. You can do this using the **HFSToPosixPath** XOPSupport routine.

Long Names and Paths in XOPs

In Igor Pro 8.00 and later, Igor support long object names and long file system paths.

Object names, as well as dimension labels, which were previously limited to 31 bytes, can now be up to 255 bytes.

File system paths, which were previously limited to 511 bytes on Macintosh and 259 bytes on Windows, can now be up to 2000 bytes, subject to operating system limits.

Igor commands, which were previously limited to 1000 bytes, can now be up to 2500 bytes.

Igor Pro 8 still supports existing XOPs, created with XOP Toolkit 7 and before, with the original name and path length limitations so long as the user does not pass long names or paths to the XOP. If the user attempts to pass a long name or path to an existing XOP, or if the XOP tries to access an object with a long name, Igor generates an error.

XOP Toolkit 8 supports long object names. Consequently, XOPs compiled using XOP Toolkit 8 require Igor Pro 8.00 or later. See **Choosing Which XOP Toolkit to Use** on page 5 for details.

New XOPs created by cloning an sample XOP using XOP Toolkit 8 or later will be compatible with long names and paths. For pre-existing XOPs built with earlier versions of the XOP Toolkit, in many cases, building the XOP with XOP Toolkit 8 is all you need to support long names and paths, but some changes to your source code may also be required, as explained below.

If you need to support long names and paths but also need compatibility with Igor Pro 6 or Igor Pro 7, you will need to create a new version of your XOP for Igor Pro 8 or later. Freeze your Igor Pro 6-compatible or Igor Pro 7-compatible code, create a new version of your project for Igor Pro 8, and do all new development in the Igor Pro 8-compatible project.

The next section explains how you can modify an existing XOP to support long names.

Supporting Long Names and Paths

To update an existing XOP to support long names and paths, perform these steps:

1. Change the XOPI resource in your XOP resource file (e.g., XOP1.r on Macintosh and XOP1WinCustom.r on Windows) to this:

```
// Macintosh
resource 'XOPI' (1100) {
   XOP_VERSION,            // XOP protocol version
   DEV_SYS_CODE,           // Code for development system used to make XOP
   XOP_FEATURE_FLAGS,      // Tells Igor about XOP features
   XOPI_RESERVED,           // Reserved - must be zero
   XOP_TOOLKIT_VERSION,     // XOP Toolkit version
};

// Windows
1100 XOPI                   // XOPI - Describes general XOP properties to IGOR
BEGIN
   XOP_VERSION,             // Version number of host XOP system
   DEV_SYS_CODE,            // Code for development system used to make XOP
   XOP_FEATURE_FLAGS,       // Tells Igor about XOP features
   XOPI_RESERVED,           // Reserved - must be zero
   XOP_TOOLKIT_VERSION      // XOP Toolkit version
END
```

XOP_FEATURE_FLAGS is defined in XOPResource.h. In XOP Toolkit 8 and later, XOP_FEATURE_FLAGS includes the XOP_FEATURE_LONG_NAMES bit automatically. This changes the values of the following XOPSupport macros:

MAX_WAVE_NAME	Changed from 31 to 255
MAX_OBJ_NAME	Changed from 31 to 255
MAX_DIM_LABEL_BYTES	Changed from 31 to 255
MAXCMDLEN	Changed from 400 to 2500
MAX_PATH_LEN	Changed from 511 (Macintosh) or 259 (Windows) to 2000 (Your operating system may impose a lower limit)

2. In your XOPMain function, test to make sure that you are running Igor Pro 8 or later. Here is an example:

```
   if (igorVersion < 800) {   // Requires Igor Pro 8.00 for long name support
      SetXOPResult(OLD_IGOR);
      return EXIT_FAILURE;
   }
```

OLD_IGOR must be defined in your project .h file with corresponding error strings in your .r and WinCustom.rc files. See the XOP1 project for examples.

3. Search your source code for “31” where you should have used MAX_OBJ_NAME, 32 where you should have used MAX_OBJ_NAME+1, and 400 where you should have used MAXCMDLEN. If you find such usage, change the code to use the proper macro instead of the literal number.

4. Search your source code for the following changed macros:

MAX_WAVE_NAME	Changed from 31 to 255
MAX_OBJ_NAME	Changed from 31 to 255
MAX_DIM_LABEL_BYTES	Changed from 31 to 255
MAXCMDLEN	Changed from 400 to 2500
MAX_PATH_LEN	Changed from 511 (Macintosh) or 259 (Windows) to 2000 (Your operating system may impose a lower limit)

In the unlikely event that any of them are used in structures that you write to disk, you need to deal with compatibility issues caused by their changed size.

Search for things like this which assumes that MAX_OBJ_NAME is small:

```
char name[MAX_OBJ_NAME+1];
WaveName(waveH, name);        // Get wave name from Igor
```

```
char buffer[256];
sprintf(buffer, "Name of the wave is %s", name);
```

In this example, a very long wave name would cause a buffer overwrite. This should be changed to:

```
char buffer[MAX_OBJ_NAME+100];
sprintf(buffer, "Name of the wave is %s", name);
```

Now buffer is big enough to hold the longest wave name plus extra bytes for miscellaneous text ("Name of the wave is " in this case).

To eliminate the possibility of buffer overruns, change sprintf to snprintf:

```
char buffer[MAX_OBJ_NAME+100];
snprintf(buffer, sizeof(buffer), "Name of the wave is %s", name);
```

snprintf is guaranteed to not overwrite buffer so long as the second parameter that you pass to it is the correct size of the buffer. This prevents overwriting memory, which can cause intermittent crashes that are very difficult to debug, in the event of a bug.

5. Update the version number of your XOP.

In Xcode, update the VERS resources in your .r file if you have them. Update the “Bundle version” (CFBundleVersion) and “Bundle versions string, short” (CFBundleShortVersionString) settings in your Info.plist and Info64.plist files.

In Visual C++, right-click your .rc file in the Solution Explorer pane and choose View Code. Change the FILEVERSION and PRODUCTVERSION keys in your VERSIONINFO resource as well as the strings in the StringFileInfo block.

6. Clean your project.

In Xcode, you can clean the active scheme by choosing Product→Clean.

In Visual C++, you can clean the your entire solution by choosing Build→Clean Solution.

7. Recompile your XOP.

8. Test your XOP with Igor Pro 8.00 or later.

9. Update your help file to explain that the XOP requires Igor Pro 8.00 or later because it supports long object names and paths.

Limitations of Long Name Support

External function names are limited to 31 bytes in length by the XOPF resource structure, even for XOPs that support long names and paths.

External operation names are limited to 31 bytes in length by the XOPC resource structure, even for XOPs that support long names and paths.

The name of an XOP is the name of the XOP file (e.g., "XOP1.xop") without the extensions (e.g., "XOP1). XOP Settings records written to experiment miscellaneous data are limited to 31-byte names. The name of an XOP can exceed 31 bytes, but, in this case, Igor will not send it the SAVESETTINGS message.

Limitations of Long Path Support

Igor Pro 8 or later support file paths of up to 2000 bytes. However, operating systems may impose lower limits.

On Macintosh, there is no offical length limit but empirical tests indicate a limit of 1026 bytes.

On Windows, the limit is 260 bytes except that it is higher on Windows 10, version 1607 or later, if your system is configured to support long paths. Search the web for LongPathsEnabled for details.

Alerts and Message Boxes

The following routines provide a cross-platform way to display simple alert dialogs.

Routine	What It Does
XOPOKAlert	Displays a message with an OK button.
XOPOKCancelAlert	Displays a message with OK and Cancel buttons.
XOPYesNoAlert	Displays a message with Yes and No buttons.
XOPYesNoCancelAlert	Displays a message with Yes, No, and Cancel buttons.

Open and Save File Dialogs

These routines provide a cross-platform way to implement Open File and Save File dialogs.

Routine	What It Does
XOPOpenFileDialog	Displays a standard Open File dialog.
XOPOpenFileDialog2	Displays a standard Open File dialog. Requires Igor Pro 7 or later.
XOPSaveFileDialog	Displays a standard Save File dialog.
XOPSaveFileDialog2	Displays a standard Save File dialog. Requires Igor Pro 7 or later.

Adding Dialogs

When the user selects your XOP's menu item you may want to put up a dialog. The GBLoadWaveX sample XOP does this and provides a good starting point for your XOP dialog.

Prior to XOP Toolkit 7, the XOPSupport library included cross-platform dialog support routines. Because the programming techniques used for these routines are obsolete on Macintosh, they were removed from the XOP Toolkit 7 XOPSupport library on both Macintosh and Windows. Now you must implement dialogs separately for Macintosh and Windows.

The XOP Toolkit includes an Extras folder containing files that are not part of the XOPSupport library but which may be of use. The GBLoadWaveX and VDT2 XOPs, which create dialogs, use the DialogUtilities files from the Extras folder to support dialog creation and management. On Windows, the DialogUtilities-Win.c file provides most of the routines that were removed from the XOPSupport library itself. These routines enable you to create a Windows dialog in XOP Toolkit 7 using nearly the same code as used in XOP Toolkit 6. On Macintosh, the DialogUtilitiesMac.c file provides a small subset. This is because dialog creation on Macintosh changed radically with the advent of Cocoa so the old routines are no longer of use.

On Macintosh, you implement a dialog using Apple's Cocoa framework. The GBLoadWaveX sample XOP provides a good starting point. If you are unfamiliar with Cocoa, you will need to familiarize yourself with it.

On Windows, you can write your dialog using standard Windows programming techniques. The GBLoadWaveX sample XOP provides a good starting point.

If you are updating old XOP dialog code, see "XOP Dialogs in XOP Toolkit 7" in Appendix A of the XOP Toolkit 7 manual.

Adding Version Resources

If you plan to distribute your XOP to other people, it is a good idea to add version resources. The only use for the version resources is to identify your XOP to a person doing a Get Info in the Macintosh Finder or viewing properties in the Windows desktop. All of the sample XOPs have version resources.

Macintosh Version Resources

You create Macintosh version resources by editing your XOP's .r file. The 'vers, 1' resource identifies your XOP's version number. You can use any version number that you like. The 'vers, 2' resource identifies the version of Igor with which your XOP is intended to run.

Here is an example:

```
resource 'vers' (1) {                 // Version of XOP
   0x01, 0x00, release, 0x00, 0,      // Version bytes and country code
   "1.00",
   "1.00, © 2018 WaveMetrics, Inc., all rights reserved."
};

resource 'vers' (2) {                 // Version of Igor
   0x08, 0x00, release, 0x00, 0,      // Version bytes and country code
   "8.00",
   "(for Igor Pro 8.00 or later)"
};
```

You also must set the "bundle version string, short" (CFBundleShortVersionString) and "Bundle version" (CFBundleVersion) keys in your Info64.plist file.

Windows Version Resources

You create a version resource by editing the VERSIONINFO resource in your XOP's main .rc file.

Structure Alignment

Structure alignment controls whether fields in structures are aligned on two, four, eight or sixteen-byte boundaries and how padding between fields is used to achieve this alignment. The C and C++ languages do not define structure alignment so it is compiler-dependent.

There are two ways to set structure alignment. First, you can use a project setting to set the project-default structure alignment. Second, you can use pragma statements when defining specific structures to override the default alignment. In the XOP Toolkit we use pragma statements.

Shared Structure Alignment

Structure alignment is critical when an executable passes a structure to a separately-compiled executable, such as when Igor calls an XOP or vice versa. If they don't agree on structure alignment, they can not correctly access structure fields. This can cause bizarre crashes that are difficult to debug.

Agreement is needed only for structures passed between separately-compiled executables, such as Igor and an XOP. We call these "shared" structures.

In the XOP Toolkit, shared structures are defined with two-byte alignment. This includes structures defined in XOPSupport header files as well as structures defined in the XOP itself, namely the structures used to pass parameters to an XOP's external operations and functions. Two-byte alignment is a legacy from Igor's early days when it was the Macintosh standard alignment.

XOPSupport structures are defined in XOPSupport header files such as XOP.h and IgorXOP.h. These files contain statements to insure two-byte alignment. For example:

```
#pragma pack(2)          // All Igor structures are two-byte aligned
```

```
<Structures defined here>
```

```
#pragma pack()           // Reset structure alignment
```

In addition to the shared structures defined in XOPSupport header files, individual XOPs must also define shared structures for external operation and function parameters which they receive from Igor. Such shared parameter structures must be two-byte aligned and so must use the pragma statements shown above. Thus you will see these statements in all of the sample XOP projects.Failure to use two-byte alignment for shared structures will cause crashes that are sometimes difficult to diagnose.

File Structure Alignment

You also need to be careful about structure alignment if you store a structure in a file. Once you define the file structure, you must use the same structure and alignment in all future versions of your XOP.

If your XOP is to run cross-platform, you must use the same structure and alignment on all platforms.

WaveMetrics uses two-byte alignment for structures stored on disk.

Using Igor Structures as Parameters

You can create external functions and external operations that take structure parameters.

Structure parameters are passed as pointers to structures. These pointers always belong to Igor. You must never dispose or resize a structure pointer but you may read and write its fields.

An instance of an Igor structure can be created only in a user-defined function and exists only while that function is running. Therefore, when a structure must be passed to an external operation or function, the operation or function must be called from a user-defined function, not from the command line or from a macro. An external operation that has an optional structure parameter can be called from the command line or from a macro if the optional structure parameter is not used.

The pointer for a structure parameter can be NULL. This would happen in an external operation or function if the user supplies * as the parameter or in the event of an internal error in Igor. Therefore you must always test a structure parameter to make sure it is non-NULL before using it.

If you receive a NULL structure pointer as a parameter and the parameter is required, return an EXPECTED_STRUCT error code. Otherwise, interpret this to mean that the user wants default behavior.

You must make sure that the definition of the structure in Igor and in the XOP are consistent and you must use two-byte packing for the structure. Otherwise a crash is likely to occur.

For examples, see **External Operation Structure Parameter Example** on page 88 and **External Function Structure Parameter Example** on page 109.

Structure Fields

This table shows the correspondence between Igor structure field types and C structure field types.

Igor Field Type	C Field Type	Notes
Variable	double	
Variable/C	double[2]	
String	Handle	See **Strings In Structures** on page 195.
WAVE	waveHndl	Always check for NULL.
NVAR	NVARRec	Use with GetNVAR and SetNVAR.

Igor Field Type	C Field Type	Notes
SVAR	SVARRec	Use with GetSVAR and SetSVAR.
DFREF	DataFolderHandle	Always check for NULL.
FUNCREF	void*	Use with GetFunctionInfoFromFuncRef.
STRUCT	struct	Embedded substructure.
char	char	
uchar	unsigned char	
int16	short	
uint16	unsigned short	
int32	SInt32	
uint32	UInt32	
int64	SInt64	Requires Igor Pro 7 or later
uint64	UInt64	Requires Igor Pro 7 or later
float	float	
double	double	

If the calling Igor procedure attempts to access a non-existent wave, the corresponding waveHndl structure field will be NULL. Thus the external function must always check for NULL before using a waveHndl field.

Likewise, always check for NULL before using a DataFolderHandle field.

Do not access NVARRec and SVARRec fields directly but use the **GetNVAR**, **SetNVAR**, **GetSVAR** and **SetSVAR** XOPSupport routines instead as explained under **NVARs and SVARs In Structures** on page 196. If the calling Igor procedure attempts to access a non-existent global numeric variable or global string variable, the those routines will return an appropriate error code.

The FUNCREF field type can be used to call an Igor user-defined function or an external function that is referenced by a field in an Igor Pro structure. See **Calling User-Defined and External Functions** on page 197 for details.

Strings In Structures

Strings in Igor structures behave just like string parameters passed directly to an external operation implemented with Operation Handler. They also behave like string parameters passed directly to an external function with one important exception. In the case of a string passed as a simple external function string parameter, the XOP owns the string handle and must dispose it. In the case of a string field in a structure, Igor owns the handle and the external function *must not dispose it*.

A string field handle can be NULL. The XOP must check for NULL before using the field. A NULL string handle indicates an error in the calling user-defined function and should be treated as an error.

As with simple string parameters, strings referenced by structure fields are stored in plain Macintosh-style handles, even when running on Windows. The handle contains the string's text, with neither a count byte nor a trailing null byte. Use **WMGetHandleSize** to find the number of characters in the string. To use C string functions on this text you need to copy it to a local buffer and null-terminate (using **GetCString-FromHandle**) it or add a null terminator to the handle. In the latter case, you must remove the null terminator when you are finished using it as a C string. See **Understand the Difference Between a String in a Handle and a C String** on page 221 for details.

Wave Handles In Structures

Usually a waveHndl field in a structure is used to pass a wave reference from Igor to your XOP. However, it can also be used to pass a wave reference from your XOP to Igor.

A waveHndl field will be NULL if it is uninitialized or if its initialization failed. Always test a waveHndl field before using it. If it is NULL you can return the NULL_WAVE_OP Igor error code.

If you store a wave handle in a waveHndl field of a structure you need to inform Igor by calling **HoldWave** on the structure field. By doing this, you maintain the integrity of Igor's internal wave reference count. For details see **Wave Reference Counting** on page 131.

Data Folder Handles In Structures

Usually a DataFolderHandle field in a structure is used to pass a data folder reference from Igor to your XOP. However, it can also be used to pass a data folder reference from your XOP to Igor.

A DataFolderHandle field will be NULL if it is unitialized or if its initialization failed. Always test a DataFolderHandle field before using it. If it is NULL you can return the NULL_DATAFOLDER_OP Igor error code.

If you store a data folder handle in a DataFolderHandle field of a structure you need to inform Igor by calling **HoldDataFolder** on the structure field. By doing this, you maintain the integrity of Igor's internal data folder reference count. For details see **Data Folder Reference Counting** on page 143.

NVARs and SVARs In Structures

This example illustrates handling Igor structures containing NVARs, which reference global numeric variables, and SVARs which reference global string variables.

```
#pragma pack(2)         // All Igor structures are two-byte aligned

#define kF2StructureVersion 1000       // 1000 means 1.000.
struct F2Struct {                      // Format of structure parameter.
   UInt32 version;
   NVARRec nv;       // Corresponds to NVAR field in Igor structure.
   SVARRec sv;       // Corresponds to SVAR field in Igor structure.
};
typedef struct F2Struct F2Struct;

struct F2Param {     // Parameter structure.
   F2Struct* sp;
   double result;
};
typedef struct F2Param F2Param;

#pragma pack()       // Reset structure alignment

int
XTestF2Struct(struct F2Param* p)
{
   struct F2Struct* sp;
   NVARRec* nvp;
   double realPart, imagPart;
   SVARRec* svp;
   Handle igorStrH, ourStrH;
   char buffer[256];
   int numType, err=0;

   ourStrH = NULL;
   sp = p->sp;
   if (sp == NULL)  {
      err = EXPECT_STRUCT;
      goto done;
   }
   if (sp->version != kF2StructureVersion) {
      err = INCOMPATIBLE_STRUCT_VERSION;
      goto done;
   }

   nvp = &sp->nv;                // Handle the NVAR.
   if (err = GetNVAR(nvp, &realPart, &imagPart, &numType))
      goto done;                 // Probably referencing non-existent global.
   realPart *= 2; imagPart *= 2;
   if (err = SetNVAR(nvp, &realPart, &imagPart))
      goto done;

   svp = &sp->sv;                // Handle the SVAR.
   if (err = GetSVAR(svp, &igorStrH))// igorStrH can be NULL. Igor owns it.
      goto done;                 // Probably referencing non-existent global.
   if (err = GetCStringFromHandle(igorStrH, buffer, sizeof(buffer)-1))
      goto done;                 // String too long.
   ourStrH = WMNewHandle(0L);    // We own this handle.
   if (ourStrH == NULL) {
      err = NOMEM;
      goto done;
   }
   if (err = PutCStringInHandle("Hello", ourStrH))
      goto done;
   if (err = SetSVAR(svp, ourStrH))
      goto done;

done:
   WMDisposeHandle(ourStrH);     // OK if NULL
   p->result = err;
   return err;
}
```

Calling User-Defined and External Functions

An XOP can call an Igor Pro user-defined function or an external function defined in another XOP. You might want to do this, for example, to implement your own user-defined curve fitting algorithm. This is an advanced feature that most XOP programmers will not need.

There are two ways to identify the function to be called: by the function name or using a FUNCREF field in an Igor Pro structure.

From an XOP's point of view, an Igor user-defined function and an external function defined in another XOP appear to be the same.

There are several difficulties involved in calling a user-defined function:

- You must make sure Igor's procedures are in a compiled state.
- You need some way to refer to the function that Igor and your XOP agree upon.
- You must make sure that the function's parameters and return type are appropriate for your XOP's purposes.

The XOPSupport **GetFunctionInfo**, **GetFunctionInfoFromFuncRef**, **CheckFunctionForm** and **CallFunction** routines work together with your XOP to address these difficulties. The details of each of these routines are described in Chapter 15.

GetFunctionInfo takes a function name, which you might have received as a parameter to your external operation, and returns information about the function's compilation state, its parameters and its return type. At this time you can call CheckFunctionForm to make sure that the function is appropriate for your purposes.

GetFunctionInfoFromFuncRef works the same as GetFunctionInfo except that, instead of passing the name of a function, you pass the contents of a FUNCREF field in an Igor Pro structure that you have received as a parameter.

Once you have obtained the function information, the rest of the process is the same, whether you used Get-FunctionInfo or GetFunctionInfoFromFuncRef.

Since the function may be recompiled or deleted at any time, you must call CheckFunctionForm again shortly before you attempt to call the function.

Once you have successfully called GetFunctionInfo or GetFunctionInfoFromFuncRef and CheckFunction-Form, you can call CallFunction to call the function.

CallFunction and Igor Preemptive Threads

You can call a thread-safe user-defined function or external function while you are running in an Igor pre-emptive thread. You can tell if you are running in a preemptive thread by calling **RunningInMainThread**.

When you call GetFunctionInfo, you receive information about the function in a FunctionInfo structure. The FunctionInfo structure contains an isThreadSafe field. If you are running in a preemptive thread, you must check the isThreadSafe field to make sure the function you are calling is threadsafe.

If you try to call a non-threadsafe function from a preemptive thread using CallFunction, Igor will return an error, typically the ONLY_THREADSAFE ("Function must be ThreadSafe") error.

CallFunction and Igor Independent Modules

Independent modules allow advanced programmers to create separately-compiled Igor procedure code modules. A procedure that is defined outside of any independent module exists by default in the built-in ProcGlobal module. See the Igor Pro manual for details.

When you call **GetFunctionInfo** with a simple function name, such as "MyFunction", the information returned describes the named function in the currently-executing independent module or in ProcGlobal. If you call GetFunctionInfo with a fully-qualified name, such as "ProcGlobal#MyFunction" or "MyMod-ule#MyFunction", the information returned describes the named function in the named module. So if you want to call from one independent module to another using **CallFunction**, you must use fully-qualified names when calling GetFunctionInfo. If you want to call a function in ProcGlobal, it is a good idea to specify it in the function name, as illustrated in the example below.

GetFunctionInfoFromFuncRef does not support cross-independent-module calls. It assumes that the FUNCREF passed to it was created in the module that is currently running. There is currently no way to use a FUNCREF to make cross-module calls. Use **GetFunctionInfo** with a qualified name instead.

Example of Calling a User-Defined or External Function

In this example, we have written our own curve fitting routine, analogous to Igor's FuncFit operation, as an external operation. We want to call a user or external function from our external operation.

The function that we want to call has this form:

```
Function FitFunc(w, x)
   Wave w
   Variable x
```

To simplify the example, we assume that we know the name of the function that we want to execute.

```
// Define the parameter structure.
// These are parameters we will pass to user or external function.

#pragma pack(2)             // All Igor structures are two-byte aligned
struct OurParams {          // Used to pass parameters to the function.
   waveHndl waveH;          // For the first function parameter.
   double x;                // For the second function parameter.
};
typedef struct OurParams OurParams;
typedef struct OurParams* OurParamsPtr;
#pragma pack()              // Reset structure alignment

int
DoOurOperation(waveHndl coefsWaveH)
{
   FunctionInfo fi;
   OurParams parameters;
   int badParameterNumber;
   int requiredParameterTypes[2];
   double result;
   int i;
   double values[5];
   int err;

   // Make sure the function exists and get information about it.
   if (err = GetFunctionInfo("ProcGlobal#TestFitFunc", &fi))
      return err;

   // Make sure the function has the right form.
   requiredParameterTypes[0]=WAVE_TYPE;   // First parameter is wave
   requiredParameterTypes[1]=NT_FP64;     // Second parameter is a numeric
   if (err = CheckFunctionForm(&fi, 2, requiredParameterTypes,
                                          &badParameterNumber, NT_FP64))
      return err;

   // We have a valid function. Let's call it.

   parameters.x = 0;
   parameters.waveH = coefsWaveH;
   for(i=0; i<5; i+=1) {
      parameters.x = i;
      if (err = CallFunction(&fi, (void*)&parameters, &result))
         return err;
      values[i] = result;
   }

   return 0;
}
```

Calling User-Defined Functions That Return Multiple Results

Starting with Igor Pro 8.00, a user-defined function can return more than one result. This is described in Igor's "Multiple Return Syntax" help topic. The rest of this section assumes that you have read and understood that help topic. For brevity, we will refer to user-defined functions that return multiple results as "MR functions".

With Igor Pro 8 and XOP Toolkit 8 or later, the **CheckFunctionForm** and **CallFunction** callbacks support the ability to call MR functions from an XOP.

Igor implements multiple results as pass-by-reference input parameters that act as if they were declared before all normal input parameters. XOP code that calls an MR function must treat multiple results accordingly. For example, this user-defined function:

```
Function [ Variable vOut, String sOut ] TestMR1(Variable vIn)
   Variable vResult = vIn + 1
   String sResult = "Hello"
   return [ vResult, sResult ]
End
```

acts like this:

```
Function TestMR2(Variable& vOut, String& sOut, Variable vIn)
   Variable vResult = vIn + 1
   String sResult = "Hello"
   vOut = vResult
   sOut = sResult
End
```

In order to call TestMR1 from an XOP, you treat it as if it were declared like TestMR2. That is, when calling CheckFunctionForm and CallFunction, you provide three required parameters with the first two being pass-by-reference parameters. To signify that there is no direct result, you use FV_NORETURN_TYPE as the last parameter to CheckFunctionForm and nullptr as the last parameter to CallFunction.

Here is code that calls TestMR1:

```
#pragma pack(2)
struct CallTestMR1Params {
   double vOut;               // Output parameter - pass-by-reference
   Handle sOutH;              // Output parameter - pass-by-reference
   double vIn;                // Input parameter - pass-by-value
};
typedef struct CallTestMR1Params CallTestMR1Params;
#pragma pack()

static int
CallTestMR1(FunctionInfo& fi)
{
   FunctionParams functionParams;
   FunctionInfo fi;
   int badParameterNumber;
   int requiredParameterTypes[3];
   int err;

   // Multiple return requires Igor Pro 8.00 or later
   if (igorVersion < 800)
      return NOT_IMPLEMENTED;

   // Make sure the function exists and is of the expected form.
   if (err = GetFunctionInfo("TestMR1", &fi))
      return err;
   requiredParameterTypes[0] = NT_FP64 | FV_REF_TYPE;       // vOut - output
   requiredParameterTypes[1] = HSTRING_TYPE | FV_REF_TYPE;  // sOutH - output
   requiredParameterTypes[2] = NT_FP64;                     // vIn - input
   if (err = CheckFunctionForm(&fi, 3, requiredParameterTypes,
                               &badParameterNumber, FV_NORETURN_TYPE))
      return err;

   CallTestMR1Params functionParams;
   MemClear(&functionParams, sizeof(functionParams));// Clear vOut and sOutH
   functionParams.vIn = 123;
   /* Because the function result type is FV_NORETURN_TYPE,
      CallFunction does not set *resultPtr and we pass nullptr
   */
   err = CallFunction(&fi, &functionParams, nullptr);
   if (err != 0)
      return err;

   double vOut = functionParams.vOut;
   Handle sOutH = functionParams.sOutH;   // sOutH may be NULL
   char str[256];
   GetCStringFromHandle(sOutH, str, sizeof(str)-1);

   char notice[300];
   snprintf(notice, sizeof(notice), "vOut=%g; sOut=\"%s\"" CR_STR, vOut, str);
   XOPNotice(notice);

   // We own the output string handle and must dispose it. It may be NULL.
   WMDisposeHandle(sOutH);    // Does nothing if sOutH is NULL

   return 0;
}
```

When you call CheckFunctionForm, pass-by-reference wave reference parameters must indicate a specific type of wave:

Parameter Type Code	Parameter Type	Matches
WAVE_TYPE | FV_REF_TYPE	Real numeric wave	WAVE w
WAVE_TYPE | NT_CMPLX | FV_REF_TYPE	Complex numeric wave	WAVE/C cw
TEXT_WAVE_TYPE | FV_REF_TYPE	Text wave	WAVE/T tw
WAVE_TYPE | WAVEWAVE_TYPE |FV_REF_TYPE	Wave reference wave	WAVE/WAVE ww
WAVE_TYPE | DATAFOLDER_TYPE |FV_REF_TYPE	Data folder reference wave	WAVE/DF dfw

See **CheckFunctionForm and Wave Reference Parameters** below for an explanation of the rules used to determine if a function's wave parameter is compatible with the required parameter type that you specified.

There is no guarantee that, at runtime, the actual wave type matches the declared type. Consequently, when you receive a wave handle, you should first make sure it is not NULL and then check, using **WaveType**, that its type is a type that you expect.

If you receive a wave handle as an MR output, Igor will have called HoldWave on it and you must call ReleaseWave on it when you are finished with it. This is the same as a pass-by-reference wave reference parameter as discussed in **Pass-By-Reference Wave Reference Parameters** on page 113.

If you receive a data folder handle as an MR output, Igor will have called HoldDataFolder on it and you must call ReleaseDataFolder on it when you are finished with it. This is the same as a pass-by-reference data folder reference parameter as discussed in **Pass-By-Reference Data Folder Reference Parameters** on page 116.

CheckFunctionForm and Wave Reference Parameters

When you call CheckFunctionForm, you must indicate a specific type of wave for both pass-by-value and pass-by-reference wave parameters. Use one of these values:

Wave Parameter Type Value	Parameter Type	Matches
WAVE_TYPE *	Real numeric wave	WAVE w
WAVE_TYPE | NT_CMPLX *	Complex numeric wave	WAVE/C cw
TEXT_WAVE_TYPE *	Text wave	WAVE/T tw
WAVE_TYPE | WAVEWAVE_TYPE *	Wave reference wave	WAVE/WAVE ww
WAVE_TYPE | DATAFOLDER_TYPE *	Data folder reference wave	WAVE/DF dfw

* For pass-by-reference wave parameters, you must include the FV_REF_TYPE bit (e.g., WAVE_TYPE | FV_REF_TYPE).

Igor Compiler Treatment of Wave Reference Parameters

Calling a user-defined function via CallFunction is analogous to one user-defined function calling another user-defined function in a procedure file. In that case, the Igor compiler applies rules for what types of wave references can be passed from a routine to a subroutine.

For pass-by-value wave reference parameters, the Igor compiler is very lenient - it allows you to pass any type of wave reference for any type of wave reference parameter. For example, if a subroutine declares a parameter as WAVE, the calling routine can pass a WAVE, a WAVE/C, a WAVE/T, a WAVE/WAVE, or a WAVE/DF wave reference.

For pass-by-reference wave reference parameters, the Igor compiler is stricter. You can pass any numeric wave reference as a parameter that is declared as any numeric wave reference. For example, WAVE, WAVE/D and WAVE/C can be mixed. But text wave references can be passed only for text wave reference parameters, wave wave references can be passed only for wave wave reference parameters, and data folder wave references can be passed only for data folder wave reference parameters.

The rules for pass-by-reference wave parameters also apply to wave reference results using the multiple return syntax introduced in Igor Pro 8.00.

CheckFunctionForm Treatment of Wave Reference Parameters

Like Igor's compiler, CheckFunctionForm treats numeric wave types as compatible*. If you pass WAVE_TYPE as the required type for a parameter, CheckFunctionForm accepts this if the user-defined function parameter is declared as WAVE, WAVE/D or WAVE/C but not if it is declared as WAVE/T, WAVE/WAVE or WAVE/DF.

(*There is one exception to this rule. CheckFunctionForm returns an error if you specify a complex wave (WAVE_TYPE | NT_CMPLX) as the required parameter type but the function parameter you are checking is declared as WAVE, not WAVE/C.)

For *both* pass-by-value *and* pass-by-reference wave parameters, CheckFunctionForm applies the stricter rules. You can pass any numeric wave reference as a parameter that is declared as any numeric wave reference (*see exception above) but text wave references can be passed only for text wave reference parameters, wave wave references can be passed only for wave wave reference parameters, and data folder wave references can be passed only for data folder wave reference parameters.

The rules for pass-by-reference wave parameters also apply to wave reference results using the multiple return syntax as described under **Calling User-Defined Functions That Return Multiple Results** function on page 199.

The rules stated so far in this section apply when the function you are checking, as referenced by the fip parameter, is a user-defined function. If the function that you are checking is an external function, the lenient rule are always applied (*see exception above). Igor has no way to know if an external function with a wave parameter expects a numeric wave, a text wave, a wave reference wave, or a data folder reference wave. Consequently, CheckFunctionForm does not distinguish between these types of waves when the fip parameter refers to an external function.

Always Check a Wave's Type

There is no guarantee at runtime that the actual wave matches the declared type of a wave reference. For example, Igor permits you to do this in an Igor procedure:

```
Function SubroutinePBR(w)
   WAVE& w              // Output: Numeric wave reference
   Make/O/T tw {"Red", "Green", "Blue"}
   WAVE w = $"tw"       // Numeric wave reference w points to text wave
End

Function CallingRoutinePBR()
   WAVE w
   SubroutinePBR(w)     // Numeric wave reference w points to text wave
   Print(w)
End
```

Assume that CallingRoutinePBR is an external function that calls the user-defined function SubroutinePBR via CallFunction. CheckFunctionForm would not complain because both the required parameter type and the declared parameter type (as declared by SubroutinePBR) are pass-by-reference references to numeric waves (WAVE&). But at runtime, CallingRoutinePBR would receive a reference to a text wave, not to a numeric wave. If CallingRoutinePBR treated the received wave handle as numeric, a crash would likely result.

To prevent crashes, when you receive a wave handle, you must perform two checks:

1. Check if the wave handle is NULL and return an error if so

2. Using **WaveType**, check that the wave's type is a type that you can handle and return an error code if not

Checking For Aborts

If your external operation or external function might take a long time to finish you will probably want to allow the user to abort it. There are two XOPSupport routines to help with this, **SpinProcess** and **CheckAbort**.

SpinProcess is so-named because originally it spun the beachball cursor during a lengthy calculation on Macintosh. Now the operating system spins the beachball if the program stops responding to events. However, in Igor Pro 7 or later, SpinProcess still spins the beachball in the bottom/right corner of the status area.

SpinProcess returns non-zero if an abort has occurred because:

- The user pressed cmd-dot (Macintosh) or Ctrl-Break (Windows)
- The user clicked the Abort button in the status area
- A procedure called the Abort operation

Otherwise SpinProcess returns zero.

You can call SpinProcess from a lengthy loop like this:

```
   int err = 0;
   for(i=0; i<1E9; i+=1) {          // This will take a long time
      <do one iteration of your calculation>
      if ((i % 100) == 0) {         // Do this every 100 iterations
         if (SpinProcess() != 0) {
            err = -1;               // -1 signals an cancel or abort
            break;
         }
      }
   }
   return err;
```

SpinProcess does a callback to Igor which can take some time. That's why we call SpinProcess every 100 iterations instead of every iteration. You can adjust the number 100 to suit your situation. To achieve reasonable responsiveness, SpinProcess should be called at least a few times per second if practical.

NOTE: Calling SpinProcess, or any other callback, may cause recursion. This can cause your XOP to crash if you do not handle it properly. See **Handling Recursion** on page 66 for details.

CheckAbort checks for the user pressing the abort key combinations at the moment you call it and does not check for the other abort conditions listed above. CheckAbort does not do a callback to Igor and is therefore faster than SpinProcess and does not introduce the possibility of recursion. Also CheckAbort is thread-safe with any version of Igor.

On Macintosh CheckAbort may not work correctly on non-English keyboards. It checks the key that is the dot key on an English keyboard. This is the key that is two keys to the left of the righthand shift key. On a French keyboard, for example, that is the colon key so you must press cmd-colon instead of cmd-dot.

If this is a problem, use SpinProcess instead of CheckAbort.

64-bit Integer Issues

Igor Pro 7 added the ability to create signed and unsigned 64-bit integer waves. The XOP Toolkit supports such waves, but there are many issues.

For almost all applications, you should use double waves rather than 64-bit integer waves.

Doubles (64-bit floating point) can represent integers precisely if the integer fits in 53 bits. Thus, the largest integer that is precisely represented by a double is 2^53-1 which equals 9,007,199,254,740,991 which is roughly 9 quadrillion.

Doubles represent integers larger than 9 quadrillion approximately. This means that any time Igor, your XOP, or Igor procedure code stores a very large integer in a double, precision is lost. This is usually not a problem because it is very rare for programs to need to represent integers larger than 9 quadrillion.

Internally, Igor uses doubles for most calculations. Consequently, if you use 64-bit integer waves in calculations, it takes time to do this conversion and you lose precision to boot. Furthermore, the conversion of very larger integers from 64-bit integer to double may cause internal overflow errors giving incorrect results.

Here is an example showing an overflow error:

```
Function Demo()
   Make/O/D/N=2 FP64
   Make/O/L/N=2 SInt64
   Edit FP64, SInt64
   ModifyTable format(FP64)=1, width(FP64)=150
   ModifyTable format(SInt64)=1, width(SInt64)=150

   FP64[0] = 9007199254740991          // Represented precisely
   FP64[1] = 9223372036854775807       // Represented approximately
   SInt64[0] = FP64[0]                 // Correct
   SInt64[1] = FP64[1]                 // Incorrect due to overflow
End
```

This produces the following table:

	FP64	SInt64
0	9007199254740991	9007199254740991
1	9223372036854775808	-9223372036854775808

The statement:

```
FP64[1] = 9223372036854775807
```

gave us a value of 9223372036854775808 for FP64[1] because 9223372036854775807 can not be precisely represented in a double.

The value of SInt64[1] is wrong. This statement

```
SInt64[1] = FP64[1]
```

has to convert from double-precision floating point to signed 64-bit integer. In this case, the value represented by FP64[1] is too big to fit in a signed 64-bit integer. Overflow occurs and we get an incorrect result.

In principal it is possible for the conversion from double to signed 64-bit integer to include clipping so that we would get 9223372036854775807 from the statement. However, clipping is time consuming, and to find and fix every place in Igor where clipping is needed is practically impossible and would likely introduce bugs.

Tables in Igor Pro 7 use doubles internally and thus do not properly handle the entry or display of very large integers. In Igor Pro 8, tables properly handle very large 64-bit integers.

The point of this section is that the use of 64-bit integers comes with pitfalls. This is why, for nearly all applications, you should use double rather than 64-bit integers.

Using 64-bit integer waves is appropriate if you are dealing with a data source that produces 64-bit integer data and if there is a chance that such data may exceed 9 quadrillion in magnitude. In this case, you can use 64-bit integer waves, but you should be aware of the issues raised in this section.

To retrieve or store 64-bit integer data from 64-bit integer waves, you must use **The Direct Access Method** (see page 126) or one of these routines:

MDGetNumericWavePointValueSInt64	**MDSetNumericWavePointValueSInt64**
MDGetNumericWavePointValueUInt64	**MDSetNumericWavePointValueUInt64**

Writing XOPs in C++

Writing an XOP in C++ is not significantly different from writing it in C.

Calling C Code from C++ Code

In general, your C++ XOP code will use XOPSupport routines or other functions that obey the C calling convention. To use a C routine in your C++ code, you must use the extern "C" declaration when declaring C routines. For example, if the C function foo is declared in its original C file as:

```
   void foo(int i);
```

you need to add to any C++ file that contains a call to the function the following declaration:

```
   extern "C" void foo(int i);
```

To simplify the process, header files for most libraries, including the XOPSupport headers, have the following structure:

```
#ifdef __cplusplus
extern "C" {
```

```
#endif

...

file definitions, declarations and prototypes

...

#ifdef __cplusplus
}
#endif
```

This structure ensures that when the header file is included in a C++ module, it automatically contains proper extern declarations for all of its C functions. Because the XOPSupport headers have this structure, you don't need to worry about `extern "C"` declarations when you use XOPSupport routines in your C++ files.

C++ Code Called From C Code

Since Igor must work with both C and C++ XOPs, it uses C calling conventions when calling an XOP function. Thus your XOPMain function, XOPEntry function, and any external operation or external function execute routines in C++ source files must be declared `extern "C"`. For example:

```
HOST_IMPORT int      // HOST_IMPORT includes extern "C" in C++ code
XOPMain(IORecHandle ioRecHandle)

extern "C" void      // XOPEntry routine
XOPEntry(void)

extern "C" int       // External operation execute routine
ExecuteXOP1(XOP1RuntimeParamsPtr p)

extern "C" int       // External function execute routine
XFUNC1Div(XFUNC1DivParams* p)
```

Using C++ Exceptions

If your C++ code uses C++ exceptions, all exceptions thrown from within your XOP must be caught inside your XOP. This includes exceptions thrown by C++ library routines that you call. Otherwise the exception will cause Igor to crash.

Windows DLL Dependencies

Igor loads Windows XOPs using the Windows OS LoadLibraryEx routine with the LOAD_WITH_ALTERED_SEARCH_PATH flag. This means that the OS will look for DLLs required by the XOP in the folder containing the XOP before looking elsewhere. You can ship a DLL that your XOP depends on in the same folder as the XOP and no further installation is required of the end user. This technique is explained at:

http://msdn.microsoft.com/en-us/library/ms682586(VS.85).aspx

Providing Help

Overview

If your XOP will be used by other people, you should provide help. This chapter explains how to do that.

Igor Pro Help File

If your XOP is to be used by people other than you, you should create an Igor Pro help file. Igor uses this help file to display help in the Igor Help Browser Command Help tab and to provide templates in Igor procedure windows. You can also ask Igor to display this file when the user clicks the Help button in your dialog or window. The user can open the help file at any time by double-clicking it or using the File→Open File→Help File menu item.

Igor Pro help files work on both Macintosh and Windows. You can edit the file on one platform and use it on both. The help file name must have a ".ihf" extension. After editing the file as an Igor formatted notebook, the next time you open it as a help file, Igor will “compile” it.

The help compiler generates a list of topics and subtopics and their locations in the help file. Its output is stored in the help file itself. You can compile your help file on either platform and it will work on both.

Your help file should include an overview, installation instructions, examples of using your XOP, and a description of each operation and function that your XOP adds to Igor.

It is usually best to start with a help file for one of the sample XOPs and modify it to suit your purposes. For details on creating an Igor Pro help file, see the Igor Pro User’s Manual.

When Igor needs to find an XOP’s help file, to display help in the Help Browser, for example, it looks in the folder containing the executable XOP itself. The sample XOPs use a folder organization, described in Chapter 3, which puts the executable XOP in a development system-specific subfolder. The help file is at the top of the sample XOP folder hierarchy, usually one level up from the executable XOP. You can make Igor find the help file by putting an alias (*Macintosh*) or shortcut (*Windows*) for it in the same folder as the executable XOP. The alias or shortcut must have the exact same name as the help file itself.

Help for External Operations and Functions

Igor Pro provides help for built-in operations and functions via the Command Help tab of the Igor Help Browser and also via the Templates popup menu in the procedure window. Your XOP can supply this kind of help for its own operations and functions.

When Igor Pro builds the list in the Command Help tab and when it builds the Templates popup menu, it automatically includes any external operations declared in your XOP’s XOPC resource and any external functions declared in your XOP’s XOPF resource.

When the user chooses an external operation or function that your XOP provides, Igor Pro looks in the folder containing the executable XOP for your XOP's help file. If it finds it, it looks in the help file for a subtopic that matches the operation or function. If it finds this, it displays the help in the Help Browser or displays the template in the procedure window.

By default Igor looks for an XOP help file in the same folder as the XOP file itself with the same name as the XOP file, minus the “64” for 64-bit XOPs, and with " Help.ihf" appended. If the XOP file name is "GBLoadWaveX.xop" or "GBLoadWaveX64.xop", Igor looks for "GBLoadWaveX Help.ihf". This is what we call the "default help file name". In most case, the default name is fine so this technique will work.

You may want to override the default help file name. For example, you might have an XOP named "GBLoadWaveX Release" and another XOP named "GBLoadWaveX Debug", and you want both XOPs to use a single help file named "GBLoadWaveX Help.ihf". To override the default help file name, you must put a STR# 1101 resource in your XOP's resource fork. Igor takes item number 3 in this resource, if it exists, as the help file name. Here is an example from GBLoadWaveX.

```
// Macintosh, in GBLoadWaveX.r.
resource 'STR#' (1101) {          // Misc strings that Igor looks for.
   {
      "-1",
      "---",
      "GBLoadWaveX Help",         // Name of XOP's help file.
   }
};

// Windows, GBLoadWaveXWinCustom.rc.
1101 STR#                         // Misc strings that Igor looks for.
BEGIN
   "-1\0",
   "---\0",
   "GBLoadWaveX Help\0",          // Name of XOP's help file.

   "\0"                           // 0 required to terminate the resource.
END
```

The first two items in the STR# 1101 resource are not used by modern XOPs. The first item must be -1. It is the third item that defines the custom XOP help file name. Note that the ".ihf" extension is not included in the resource string but is included in the help file name.

If Igor finds the help file using your custom help file name from STR# 1101 or the default help file name, it then looks in the help file for a subtopic whose name is the same as the name of the operation or function for which the user has requested help. If it finds such a subtopic, it displays the subtopic text in the dialog. Note that subtopics must be governed by a ruler whose name is "Subtopic" or starts with the letters "Subtopic". The best way to create your help file is to start with a WaveMetrics help file and modify it.

Programmatically Displaying a Help Topic

You may want to display a help topic from your help file when the user clicks a Help button in a dialog or at some other time. You can do this by calling **XOPDisplayHelpTopic** XOPSupport routine.

Chapter 14

Debugging

Overview

In this chapter we present tips and techniques learned through years of XOP programming that may save you valuable time.

Most bugs can be avoided by careful programming. You can dramatically reduce the amount of time that you spend debugging by using good programming practices. These include

- Breaking your program up into appropriate modules
- Using clear and descriptive variable and function names
- Always checking for errors returned by functions that you call
- Keeping the use of global variables to a bare minimum
- Carefully proofreading your code immediately after writing it

The best time to find a bug is when you create it. When you write a routine, take a few minutes to *carefully proofread it*. Be on the lookout for the common errors listed below that can take hours to find later if you don't catch them early.

Most of the problems that people run into in writing XOPs are standard programming problems. We discuss several of them in the next section. The middle part of the chapter discusses debugging techniques. The chapter ends with a discussion of pitfalls that are specific to XOP programming.

Programming Problems

Here are some of the common programming problems that you should be on the lookout for as you proofread your code.

Excessive Use of Global Variables

Global variables are bad because any routine in your program can change them and any routine can depend on them. This can lead to complex and unexpected dependencies which in turn leads to intermittent bugs that are very difficult to fix. A given routine may change a global variable, having an unforeseen impact on another routine that uses the global. This creates a bug that may manifest itself at unpredictable times.

By contrast, a routine that accesses no global variables depends only on its inputs and can not impact routines other than the one that called it. This makes it easy to verify that the routine works properly and reduces the likelihood of unforeseen effects when you change the routine.

You can avoid using globals by passing all of the necessary information from your higher level routines to you lower level routines using parameters. This does lead to routines with a lot of parameters but this is a small price to pay for robustness.

It is alright to use global variables for things that you can set once at the beginning of your program and then never need to change. For example, the XOPSupport routines use a global variable, XOPRecHandle, to store the handle that Igor uses to communicate with your XOP. This global is set once when your XOP calls XOPInit and then is never changed. Because it is never changed, it can't introduce complex dependencies.

Uninitialized Variables

The use of uninitialized variables can be difficult to find. Often an uninitialized variable problem shows up only if your code takes a certain execution path. Here is an example.

```
int numBytes;
double* dp;

if (<condition1>)
   numBytes = 100;
else
   if (<condition2>)
      numBytes = 200;

dp = (double*)WMNewPtr(numBytes);      // Possible bug
<Fill block with data>;
```

If neither <condition1> nor <condition2> is true, then numBytes will be uninitialized. This may happen only in rare cases so your code may seem to run fine, but once in a while it crashes or behaves erratically.

Even if numBytes is uninitialized, your code may run fine some times because numBytes just happens to have a value that is sufficient. This makes it even harder to find the problem because it will be very intermittent.

If this bug is symptomatic, the symptom will most likely be a crash. However, the crash may occur some time after this routine executes successfully. The reason is that this routine will clobber the block of memory that falls after the block allocated by WMNewPtr. You will not actually crash until something tries to use the clobbered block.

To avoid this problem, *proofread your code* and pay special attention to conditional code, making sure that all variables are initialized regardless of what path execution takes through the code.

Overwriting Arrays

It is not too difficult to clobber data on the stack or in the heap by overwriting an array. Here is an example.

```
int
Test(char* inputName)
{
   char name[MAX_OBJ_NAME+1];
   Handle aHandle;

   aHandle = WMNewHandle(100);
   if (aHandle == NULL)
      return NOMEM;
   strcpy(name, inputName);
   strcat(name, "_N");           // Possible bug
   .
   .
   .
}
```

This code will work fine as long as the inputName parameter is less than or equal to MAX_OBJ_NAME-2 characters long. This is likely to be the case most of the time. Once in a while, it may be longer. This will cause the strcat function to overwrite the name array. The effect of this will depend on what follows the name array in the local stack frame.

With most compilers, the aHandle variable will follow the name array on the local stack. Thus, this bug will clobber the aHandle variable. This will most likely cause a crash when the aHandle variable is used or when it is disposed. It could be worse though. It may corrupt the heap when aHandle is used but not cause a crash until later, making it very difficult to track down.

Here is a very insidious case in which the bug may be asymptomatic most of the time. Imagine that the inputName parameter is MAX_OBJ_NAME-1 characters long. Then, the strcat function will use just one more byte than is allocated for the name array. It will write the terminating null character for the name variable in the first byte of the aHandle variable. If the first byte of aHandle was already 0, this will be asymptomatic. If it was not 0, it will likely cause a crash when aHandle is used or disposed. The crash will be intermittent, making it difficult to fix.

To avoid this problem, *proofread your code* and pay special attention to array and string operations, keeping in mind the possibility of overwriting. Read through the code assuming a worst case scenario (e.g., inputName is as long as it possibly could be).

Off By One Errors

It is very easy and common to do something one time too many or one time too few. For example.

```
int
RotateValuesLeft(float* values, int numValues)
{
   float value0;
   int i;

   value0 = values[0];
   for(i = 0; i < numValues; i++)
      values[i] = values[i+1];    // Bug
   values[numValues] = value0;    // Bug
}
```

We assume that values parameter points to an array of numValues floats. There are two problems here. First, when i reaches its maximum value (numValues-1), values[i+1] accesses a value that is past the end of the array. Second, and more destructive, the last statement clobbers whatever happens to be stored after the values array. If the values array is in the heap, this may cause heap corruption and a crash at some later time. If the values array is on the stack, it may or may not cause a problem, depending on what is stored after the values array and how it is used.

To avoid this problem, *proofread your code* and pay special attention to what happens the first and last times through a loop. In this example, assume that numValues is some specific number (3, for example) and work through the loop, paying special attention to the last iteration. Also verify that the last element of an array is being set and that no element beyond the last element is being touched. Remember that, for an array of n elements, the first valid index is zero and the last valid index is n-1.

Failure To Check Error Codes

Always check error codes returned from XOPSupport routines (and any other routines, for that matter) and handle errors gracefully. Failure to check error codes can turn a simple problem into a devilish, irreproducible crash. Here is an example.

```
void
BadCode(void)
{
   char* waveData;
   CountInt dims[MAX_DIMENSION_SIZES+1];

   MemClear(dims, sizeof(dims));
   dims[ROWS] = 100;
   dims[COLUMNS] = 100;
   MDMakeWave(&waveH, "wave0", NULL, dims, NT_FP32, 1);
   waveData = (char*)WaveData(waveH);
   MemClear(waveData, 100*100*sizeof(float));
}
```

MDMakeWave returns an error code, but this routine ignores it. If memory is low, MDMakeWave may fail, return NOMEM as the error code, and leave waveH undefined. The XOP will crash when it calls WaveData or MemClear. Since this will happen under low memory conditions only, it will happen irreproducibly and the cause will be hard to find.

The code should be written like this.

```
int
GoodCode(void)
{
   char* waveData;
   CountInt dims[MAX_DIMENSION_SIZES+1];
   int err;

   MemClear(dims, sizeof(dims));
   dims[ROWS] = 100;
   dims[COLUMNS] = 100;
   if (err = MDMakeWave(&waveH, "wave0", NULL, dims, NT_FP32, 1))
      return err;
   waveData = (char*)WaveData(waveH);
   MemClear(waveData, 100*100*sizeof(float));
   return 0;
}
```

Misconceptions About Pointers

People who program infrequently in C sometimes forget that a pointer has to point to something. Here is an example of a common error.

```
void
F1(int* ip)
{
   *ip = 0;
}

void
F2_BAD(void)
{
   int* ip1;

   F1(ip1);                      // Bug
}
```

The variable ip1 is a pointer to an int so the compiler is happy with this code. At runtime, however, it may cause a crash. The problem is that ip1 is an uninitialized variable. It contains a random value that could point to any location in memory. When F2_BAD calls F1, F1 sets the value pointed to by ip1 to zero. This sets a random 32-bit section of memory to zero. It could be completely asymptomatic or it could cause an immediate crash or it could cause a crash at a later time. It could cause just about anything. It depends on what value happens to be stored in ip1.

This example shows two correct ways to call F1.

```
void
F2_GOOD(void)
{
   int int1;
   int ip1;

   F1(&int1);
   ip1 = (int*)WMNewPtr(sizeof(int));
   if (ip1 != NULL) {
      F1(ip1);
      WMDisposePtr((Ptr)ip1);
   }
}
```

In the first call to F1, we pass the address of the local variable int1 which we have allocated on the local stack. In the second call to F1, we pass the address of a block of memory in the heap that we have allocated using WMNewPtr.

To avoid problem with pointers, keep in mind that a pointer variable is just a variable that holds the address of some place in memory and that you must set the value of the pointer to make it point to memory that you have allocated before you use it. When you use a pointer, give some thought to whether it points to some space on the local stack (&int1 in F2_GOOD) or to some space in the heap (ip1 in F2_GOOD). This will help you avoid uninitialized pointers.

Using Memory Blocks That You Have Not Allocated

This is really another case of an uninitialized variable. We make a special case of this because it is a common one with dire consequences. Here is an example.

```
int
Test(int v1, int v2)
{
   Handle h;
   BCInt size;
   int err = 0;

   size = v1 * v2;
   if (size > 0) {
      h = WMNewHandle(size);
      <Do something with the handle>;
   }

   WMDisposeHandle(h);        // Possible bug
   return err;
}
```

We dispose the handle even in the case where size <= 0. In that case, we will not have allocated the handle. This may or may not be symptomatic, depending on what value happens to be stored in the handle. If it happens to be 0 (NULL), then is will be asymptomatic. Otherwise, it is likely to crash.

This problem is usually a lot more subtle than this example illustrates. The function may have all sorts of conditionals, loops and switches and there may be certain paths of execution in which the handle is not allocated. Often the best solution for this is to use the handle itself as a flag indicating whether or not it has been allocated. For example:

```
int
Test(int v1, int v2)
{
   Handle h;
   BCInt size;
   int err = 0;

   h = NULL;                  // Flag that handle has not been allocated
   size = v1 * v2;
   if (size > 0) {
      h = WMNewHandle(size);
      <Do something with the handle>;
   }
   if (h != NULL)              // Test flag
      WMDisposeHandle(h);
   return err;
}
```

In this particular case, the test for h being NULL is not needed as WMDisposeHandle does nothing if its parameter is NULL.

Using Memory Blocks That You Have Disposed

Disposing Memory Blocks More Than Once

These problems are similar to the preceding one in that they generally occur in a complex function that has many potential execution paths. They can also happen if you use global variables. For example:

```
static Handle gH;             // A global handle variable.

void
InitializePart1(void)
{
   BCInt size;

   size = WMGetHandleSize(gH);// Uses global before it is initialized.
   memset(**gH, 0, size);
}

void
InitializePart2(void)
{
   gH = WMNewHandle(100);     // Initializes global handle.
}

void
XOPMain(void)
{
   InitializePart1();
   InitializePart2();
}
```

The problem here is confusion as to which routine is responsible for what. InitializePart1 assumes that gH has already been allocated but it has not. So it is using a garbage handle with unpredictable results but most likely a spectacular crash. This illustrates one of the fundamental problems with global variables - it is difficult to remember when they are valid and what routines have the right to use them.

To avoid this problem, pay special attention to the allocation and deallocation of memory blocks during coding and proofreading. Make sure that each is allocated once and disposed once. It is good practice to initialize pointers and handles to NULL and test for NULL before allocating or disposing the memory to which they refer. After disposing, reset the pointer or handle to NULL.

Failure to Dispose Memory Blocks

This problem is commonly called a “memory leak”. It occurs when you forget to deallocate a block that you have allocated. This is usually not fatal - it just consumes memory unnecessarily.

One way to avoid this problem is to proofread your code carefully, paying special attention to all memory allocations.

Make sure that you know, when you receive a handle from Igor, whether the handle belongs to Igor or is yours to dispose. The XOP Toolkit documentation tells you which of these is the case. For example, when your external function receives a handle containing a string parameter, the handle belongs to you and you must dispose it. However, when your external operation receives a string handle, it belongs to Igor and you must not dispose it. These issues are discussed in Chapter 5 and Chapter 6.

You can check for leaks by writing a loop that calls your XOP over and over while monitoring memory usage. On MacOS, you can use Activity Monitor or MallocDebug or Xcode's Leaks performance tool. On Windows you can use the Task Manager. Third-party leak detection tools are also available.

Keep in mind that some fluctuation in memory allocation is normal. For example, the first time you call your external operation or function, Igor or your XOP may allocate some memory that needs to be allocated only once. But if memory usage continues to grow without explanation as you call your XOP over and over then you may have a leak.

If you find a memory leak you will also discover that it can be very difficult to track down. It is much better to code carefully in the first place than to spend your time chasing leaks. Coding carefully in this case means having a clear idea of when memory is allocated and when it is deallocated, avoiding complicated schemes and *carefully proofreading* your code after you write it.

Disposing Memory Blocks That Don't Belong to You

Wave and data folder handles belong to Igor, not you. Thus you should never dispose them directly, i.e., using WMDisposeHandle.

String handles that Igor passes to you sometimes remain owned by Igor and sometimes become owned by you. For example, string handles passed as parameters to your external function are owned by you and you must dispose them. But string handles passed as parameters to your external operations remain owned by Igor and you must not dispose them. Consult the XOP Toolkit documentation for the feature or XOPSupport routine you are using. It tells you when a handle belongs to Igor and when it is yours to dispose.

A similar situation arises with libraries that you might use. Whenever you receive a pointer or handle from a library, you must be certain about who is responsible for eventually deleting it. Check the documentation and understand who owns each memory resource.

Failure to Check Memory Allocations

If your XOP works fine most of the time but crashes under low memory conditions, it is possible that you have failed to check memory allocations. Here is an example:

```
void
Test()
{
   Handle h;
   h = WMNewHandle(10000);
   memset(*h, 0, 10000);      // Possible bug
}
```

Under sufficiently low memory, the WMNewHandle call will fail and h will contain 0. The memset function will attempt to clear the first 10000 bytes starting at address 0 and will cause an access violation exception. The routine should be rewritten like this:

```
int
Test()
{
   Handle h;
   h = WMNewHandle(10000);
   if (h == NULL)
      return NOMEM;
   memset(*h, 0, 10000);
   return 0;
}
```

Now that Test detects low memory, it will no longer cause an exception. However, the routine that called Test will need to know that an error has occurred and must be able to stop whatever it was doing and return an error also. In fact, all of the routines in the calling chain that led to Test need to be able to cope with an error. For a program to be robust, it must be able to gracefully back out of any operation in the event of an error.

Virtual memory operating systems make it hard to test how your XOP behaves under low memory conditions because memory allocation calls will almost never fail on such systems. In other words, virtual memory may camaflouge bad programming practices. Good code still always checks memory allocations and handles failed allocations gracefully.

Dangling Pointers

A dangling pointer is a pointer that used to point to a block of memory in the heap but no longer points to a valid block because the block has been freed. For example:

```
int
Bad()
{
   char* p = (char*)malloc(100);
   if (p == NULL)
      return NOMEM;
   memset(p, 0, 100);
   . . .
   free(p);                // Free the block pointed to by p
   . . .
   memset(p, 1, 100);      // BUG: p is a dangling pointer
   . . .
   return 0;
}
```

In this example the bug is obvious. But in a lengthy and complex function it is often not obvious. And if you store the pointer in a global and use it from several different functions, it becomes much harder to keep track of when it is valid.

This bug may cause an immediate crash or may cause a crash later or may be asymptomatic. It depends on what happens to be at the memory location referenced by p after the block is freed. This can create irreproducible bugs that are nasty to debug. So it is well worth your while to use good coding practices and to *carefully proofread your code* to avoid this kind of problem in the first place.

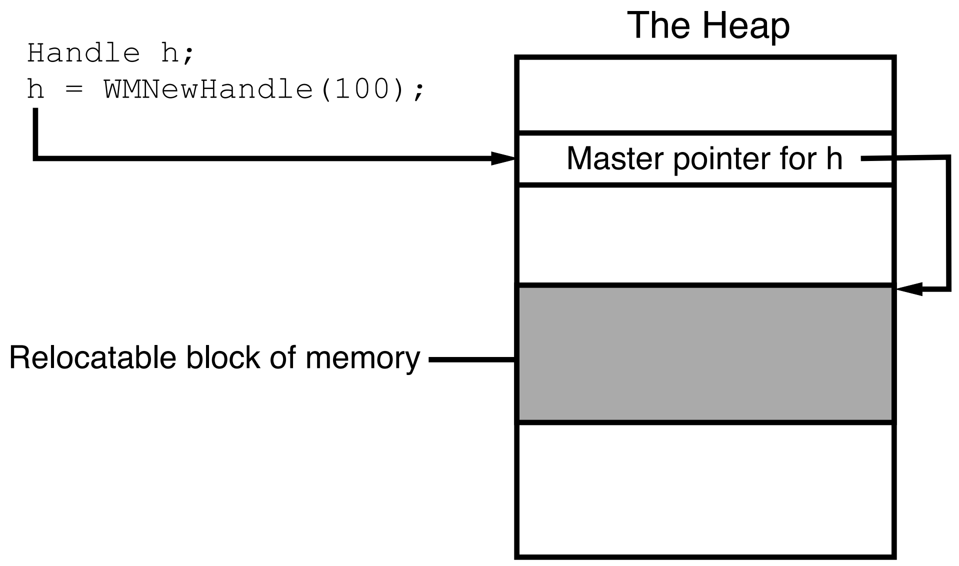
A useful technique is to use the pointer itself as a flag to determine if it is valid or not:

```
int
Good()
{
   char* p = (char*)malloc(100);
   if (p == NULL)
      return NOMEM;
   memset(p, 0, 100);
   . . .
   free(p);                // Free the block pointed to by p
   p = NULL;               // Set to NULL to signify no longer valid
   . . .
   if (p == NULL) {        // Test pointer before using
      p = (char*)malloc(100);
      if (p == NULL)
         return NOMEM;
   }
   memset(p, 1, 100);
   . . .
   free(p);
   p = NULL;              // Set to NULL to signify no longer valid
   return 0;
}
```

The last `p=NULL` statement is unnecessary because p is a local variable in this example and will cease to exist when the function returns. In a complex real-world function, it may not be so obvious so it is a good idea to consistently clear the pointer when the block it references is freed. If the pointer is a global variable, consistently clearing it is even more important.

Handles and Dangling Pointers

As explained under **Understanding Handles** on page 181, a Handle is a variable that refers to a block of memory in the heap. Unlike a pointer, which points directly to a block of memory, a Handle points to the block indirectly. Specifically, it points to a pointer, called a master pointer, to the block of memory.

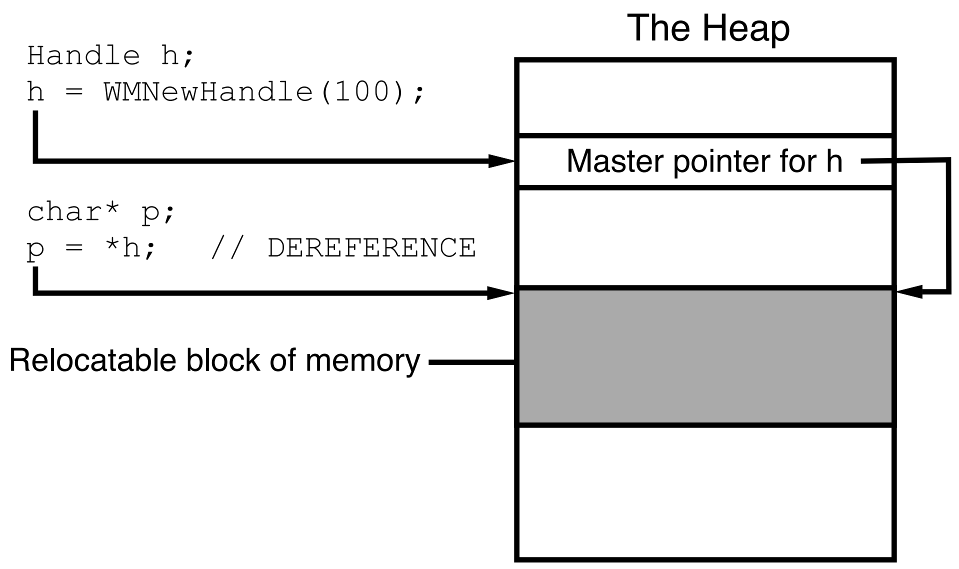


Igor uses Handles mostly for passing variable-length data, typically strings, to an XOP, and for receiving variable-length data from it. You use routines described under **WM Memory XOPSupport Routines** on page 179 to deal with Handles.

As the following sections explain, you must be careful when using a Handle to avoid using a dangling pointer to its heap block.

Dereferencing the Handle

To read or write data stored in a block of memory, we need a pointer to it. We obtain the pointer by "dereferencing" the handle, using the C * operator.



The pointer p now points to the block in memory and we can access the data using it.

The problem is that, if the memory manager moves the block in the heap in order to satisfy a request to increase the size of the block, then p will point to a place in the heap where the data no longer resides. This place may now contain a free block or it may contain the data for a different object. If we use p to read data, we will read garbage. If we use p to write data, we may trash a different block, causing a problem that will show up later.

Using a pointer obtained by dereferencing a Handle after the block of data has been moved by the memory manager is a “dangling pointer” bug.

The memory manager will not move the block of memory capriciously. It will only move the block if you try to increase its size using WMSetHandleSize either directly or indirectly. Thus you can avoid a dangling pointer bug by re-dereferencing the handle after resizing it. For example:

```
Handle h;
char* p;
int err = 0;

h1= WMNewHandle(100);
p = *h;                         // Dereference h to point to data.
memset(p, 0, 100);
. . .
err = WMSetHandleSize(h, 200);  // Increase size of heap block
if (err != 0)
   return err;
p = *h;                         // Re-dereference h to point to data.

<Use p to access data>;
```

We need to dereference h the second time because the second call to WMSetHandleSize may cause the memory manager to relocate the block of memory that h refers to.

Dereferencing Wave Handles

A wave handle is like a Handle but you must always use wave-specific XOPSupport routines, described under **Routines for Accessing Waves** on page 240, to access it. Never use generic WM memory routines to access waves.

Here is a less obvious example of a dangling pointer, this time involving a wave handle:

```
waveHndl waveH;
double* dp;
waveH = FetchWave("wave0");
if (waveH == NULL)
   return NOWAV;
<Check wave data type and number of points here>
dp = (double*)WaveData(waveH);   // Dereference wave handle
. . .
XOPCommand(<some command>);      // Call Igor to execute a command
. . .
dp[0] = 0;                       // Possible BUG
```

The bug here is that the XOPCommand call to Igor could possibly increase the size of the wave, for example, by executing Redimension on the wave. If that happened the wave's heap data could be relocated. Then dp would be a dangling pointer and the assignment statement using it could cause a crash either immediately or later.

The problem would be even more difficult to recognize if the XOPCommand call were in a subroutine called by the code above.

This bug would be asymptomatic if the wave were not resized by the Igor command or if the system was able to resize the heap block without relocating it because the memory following the heap block happened to be free. Once in a while, however, relocation would occur, with unpredictable results. In other words, this bug would cause a highly intermittent and irreproducible symptom and would be nasty to track down.

The solution is to redereference the wave handle after any call that conceivably could resize the wave. To do this, add another call to WaveData:

```
XOPCommand(<some command>);      // Call Igor to execute a command
dp = (double*)WaveData(waveH);   // Re-dereference wave handle
. . .
dp[0] = 0;
```

Dereferencing a Handle Without Using a Pointer Variable

To avoid having a dangling pointer, it is usually best to dereference the handle and use it in the same statement, if possible. This is most applicable when the handle refers to a block that contains a structure. For example, instead of:

```
StructHandle h;            // A handle to a block containing some structure.
StructPtr p;               // A pointer to a block containing the structure.
h = <Get Handle>;
p = *h;                    // Dereference.
p->field1 = 123;
p->field2 = 321;
```

we use:

```
StructHandle h;            // A handle to a block containing some structure.
h = <Get Handle>;
(*h)->field1 = 123;
(*h)->field2 = 321;
```

The benefit of this is that there is no pointer to dangle.

This technique can not be used with wave handles because you must use the WaveData or MDAccessNumericWaveData function to dereference them.

Recommendations for Using Handles

Now that we know the potential problems in using handles, how can we avoid them? There is no simple answer to this but here are some guidelines.

Avoid storing a pointer to a relocatable block in a variable. Instead, use the "Dereferencing the Handle Without Using a Pointer Variable" technique described above.

If you *must* store a pointer, as in the case of dereferencing a wave handle, re-dereference the pointer after calling *any* subroutine that could conceivably resize the block.

Debugging Techniques

This section discusses several methods for debugging an XOP:

- Using a symbolic debugger
- Using XOPNotice (equivalent to a Print statement)
- Using a crash log
- Other debugging tricks

This section does not cover the most effective debugging method: *carefully proofreading your code*. Before you spend time debugging, a simple careful reading of your code is the most effective way to find bugs. If that fails, the techniques discussed here are useful for narrowing down the suspect area of your code.

Debugging a problem that you can reproduce at will is usually not too difficult.

If you have an intermittent problem, it is useful to look for a simple set of steps that you can take to make the problem happen. If you can make the problem happen, even one time in ten, with a simple set of steps, this allows you to rule out a lot of potential causes and eventually zero-in on the problem.

Recompiling Your XOP

During the debugging process, you often need to recompile your XOP and try it again. You must quit Igor to recompile your XOP.

It is generally best to leave your executable XOP file in your project folder during development. Make an alias (*Macintosh*) or shortcut (*Windows*) for your XOP file and drag the alias or shortcut into the Igor Extensions folder to activate your XOP. This saves you the trouble of dragging the XOP file into the Igor Extensions folder each time you recompile the XOP.

Symbolic Debugging

Usually, the debugging method of choice is to use the symbolic debugger that comes with your development system. Chapter 3 includes a discussion on using the symbolic debuggers of various development systems.

Sometimes symbolic debugging does not work because the problem does not manifest itself when running under the debugger or because the bug crashes the debugger. For these cases, the following debugging techniques are available.

Debugging Using XOPNotice

The simplest tool for debugging an XOP is the XOPNotice XOPSupport routine. This lets you print a message in Igor's history area so that you can examine intermediate results and see how far your XOP is getting. For example:

```
char temp[256];
sprintf(temp, "Wave type = %d" CR_STR, WaveType(waveH));
XOPNotice(temp);
```

NOTE: When Igor passes a message to you, you *must* get the message, using GetXOPMessage, and get all of the arguments, using GetXOPItem, *before* doing any callbacks, including XOPNotice. The reason for this is that the act of doing the callback overwrites the message and arguments that Igor is passing to you.

If you call XOPNotice from an Igor preemptive thread, Igor buffers the message and prints it in the history at a later time from the main thread. This means that messages from different threads may appear in the history in an unpredictable order.

Other Debugging Tricks

In rare cases, you may want to know how your external operation or function was called.

In Igor Pro 6 or later, a simple way to do this is to invoke Igor's debugger, like this:

```
    XOPSilentCommand("Debugger");
```

If debugging is enabled (via the Procedure menu), Igor will break into the debugger after executing the current user-defined function statement – that is, after your external function or operation returns.

If no procedure is running in Igor, this statement does nothing.

You can also invoke Igor's DebuggerOptions operation using XOPSilentCommand.

You can determine the function or chain of functions that called your external function or operation using the **GetIgorCallerInfo** or **GetIgorRTStackInfo** callbacks.

Avoiding Common Pitfalls

This section lists some common problems that are specific to XOP programming.

Check Your Project Setup

See Chapter 3 for instructions on setting up Xcode and Visual C++ projects.

When in doubt, compare each of the settings in your project to the settings of an XOP Toolkit sample project.

If you are getting link errors, check the libraries in your project and compare them to the sample projects.

Get the Message and Parameters from Igor

When Igor passes a message to you, you *must* get the message, using GetXOPMessage, and get all of the arguments, using GetXOPItem, *before* doing any callbacks. The reason for this is that the act of doing the callback overwrites the message and arguments that Igor is passing to you.

This problem often occurs when you put an XOPNotice call in your XOP for debugging purposes. XOPNotice is a callback and therefore clobbers the arguments that Igor is sending to your XOP. Don't call XOPNotice or any other callback until you have gotten the message and all parameters from Igor.

Understand the Difference Between a String in a Handle and a C String

When dealing with strings, which are not limited in length, Igor uses a handle to contain the string's characters. Igor passes a string parameter to external operations and functions in a handle. There are other times when you receive a string in a handle from Igor. A string in a handle contains no null terminator. To find the number of characters in the string, use **WMGetHandleSize**.

A C string requires a null terminator. Thus, you can not use a string in a handle as a C string. Instead, you must copy the contents of the handle to a buffer and then null-terminate the buffer. The XOPSupport functions **GetCStringFromHandle** and **PutCStringInHandle** may be of use in cases where you can set an upper limit to the length of the string. Make sure that your buffer is large enough for the characters in the handle plus the null terminator.

Another approach is to append a null character to the handle, use it as a C string, and remove the null character. This is useful for cases where you can not set an upper limit on the length of the string. For example:

```
Handle h;
int len;
```

```
char* p;
int err = 0;

h = <A routine that returns a string in a handle>;
if (h != NULL) {
   len = WMGetHandleSize(h);
   err = WMSetHandleSize(h, len+1); // Make room for null terminator.
   if (err != 0)
      return err;
   *(*h+len) = 0;                   // Null terminate the text.
   p = *h;
   <Use p as a C string>;
   WMSetHandleSize(h, len);         // Remove null terminator.
}
```

There are some times when you are required to pass a string in a handle back to Igor. Again, the handle must contain just the characters in the string, without a null terminator. On the other hand, if you are passing a C string to Igor, the string must be null-terminated.

Understand Who Owns a Handle

In some cases Igor is the owner of a handle and is responsible for disposing it. In other cases, you own it and are responsible for disposing it. The XOP Toolkit documentation will tell you which is which.

For example, when your external operation receives a string parameter in a handle, Igor owns it and you must not dispose of it. By contrast, when your external function receives a string parameter in a handle, you own it and must dispose of it or pass it back to Igor as a string result in which case Igor receives ownership of it.

In the case of wave handles and data folder handles, Igor always owns these. You must never dispose of them or otherwise directly modify them using WM memory XOPSupport routines. Instead, always use the specific routines for a given type of object. These routines are listed under **Routines for Accessing Waves** on page 121 and **Routines for Accessing Data Folders** on page 285.

Choose Distinctive Names

If your XOP adds an operation or function to Igor you should be careful to choose a name that is unlikely to conflict with any built-in Igor names or user-defined names. See **Choose a Distinctive Operation Name** on page 72 and **Choose a Distinctive Function Name** on page 100 for details.

Watch Out for Recursion

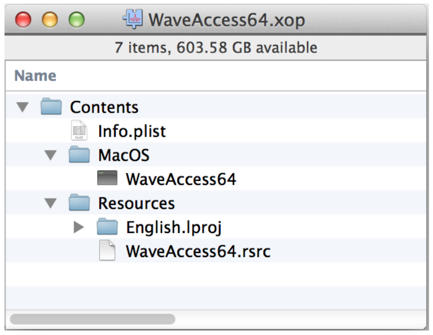
If your XOP adds a window to Igor, the DoUpdate, XOPCommand, XOPSilentCommand, and SpinProcess XOPSupport routines can cause Igor to call your XOP while your XOP is already running. See **Handling Recursion** on page 66 for details.

Structure Alignment

Make sure that all structures that might be shared with Igor are 2-byte-aligned. See **Structure Alignment** on page 193 for details.

Check Your Info.plist File

As explained under **XOP Projects in Xcode** on page 35, Macintosh XOP is a “package”. That is, it is not a simple file but rather a folder with a particular structure. To see the contents of the package folder, right-click it and choose Show Package Contents. You will see something like this:



In order for the XOP to load, the package name (e.g., **WaveAccess64**.xop) must agree with the executable name (e.g., Contents/MacOS/**WaveAccess64**) which must agree with the value of the CFBundleExecutable key in the Info.plist file (Contents/Info.plist). If any of these names are incorrect, Igor will be unable to load the XOP and usually will report “Can't load the executable file in the XOP package”.

The package’s Info.plist file is an XML file that provides information about the package to the operating system. You can view it in Xcode. One of the keys in the XML file is named CFBundleExecutable. In Xcode the CFBundleExecutable key is usually shown using its friendly name - “Executable file”.

When the XOP is compiled, Xcode copies the Info64.plist file from the project to Contents/Info.plist in the package. Thus, you should always edit the Info64.plist file in the project, not the Info.plist file in the package.

Chapter 15

XOPSupport Routines

Table of Contents

About XOPSupport Routines

The files in the XOPSupport folder define a large number of routines that communicate with Igor or provide a utility. Most XOPs will use only a small fraction of these routines. These routines are described in detail in this chapter. The chapter presents the routines in functional groups.

Some routines work only with certain versions of Igor Pro. See **Igor/XOP Compatibility Issues** on page 67 for further information on compatibility.

Routines for Communicating with Igor

These routines provide communication between your XOP and Igor.

XOPInit

```
void
XOPInit(ioRecHandle)
IORecHandle ioRecHandle;    // Used to pass info between Igor and XOP
```

The XOP must call XOPInit from its XOPMain function before calling any other callbacks.

XOPInit stores the ioRecHandle in the global variable XOPRecHandle. All XOPSupport routines that communicate with Igor use this global variable. You do not need to access it directly.

Thread Safety

XOPInit is not thread-safe.

SetXOPType

```
void
SetXOPType(type)
int type;                   // Defines capabilities and mode of XOP
```

type is some combination of TRANSIENT, RESIDENT, IDLES, and ADDS_TARGET_WINDOWS which are bitwise flags defined in XOP.h.

By default, your XOP is resident, meaning that Igor will leave it in memory once it is invoked. Except in very rare cases, you should leave your XOP as resident.

You can call SetXOPType(TRANSIENT) when your XOP is finished and you want Igor to close it. At one time this was recommended as a memory saving device. Now, however, memory is more plentiful and making your XOP transient is likely to cause more trouble than it prevents. XOPs that define external operations or functions must not be transient because they need to remain memory-resident. Igor ignore this call if your XOP adds an external operation or function.

Call SetXOPType(RESIDENT | IDLES) if you want to get periodic IDLE messages from Igor. This is appropriate, for example, in data acquisition XOPs.

The ADDS_TARGET_WINDOWS bit has to do with XOP target windows. This is no longer supported and the bit is ignored.

See **The IORecHandle** on page 64 for details.

Thread Safety

SetXOPType is not thread-safe.

SetXOPEntry

```
void
SetXOPEntry(entryPoint)
ProcPtr entryPoint;         // Routine to handle all messages after INIT
```

Identifies to Igor the routine in your XOP which services all messages after INIT.

You must call this from your XOPMain function, passing it the address of your XOPEntry routine.

Thread Safety

SetXOPEntry is not thread-safe.

SetXOPResult

```
void
SetXOPResult(result)
int result;                   // Result of XOP operation
```

Sets the result field of your XOP's IORecHandle.

Igor looks at the result field when your XOP returns. The result is usually an error code in response to the CMD, FUNCTION or MENUITEM messages from Igor. For other messages from Igor, the result may be some other value.

Do not use SetXOPResult to return errors from a direct external operation or function. For a direct operation or function, the CMD or FUNCTION message is not sent to your XOPEntry routine. "Direct" means that your function is called directly from Igor, not through your XOPEntry routine. Such functions return result codes as the function result.

New external operations and functions should be direct.

See **XOP Errors** on page 59 for details on error codes.

Thread Safety

SetXOPResult is not thread-safe.

GetXOPResult

```
XOPIORecResult
GetXOPResult(void)
```

Returns the contents of the result field of your XOP's IORecHandle.

This is used by XOPSupport routines to get the result of a callback to Igor. You should not call it yourself.

Thread Safety

GetXOPResult is not thread-safe.

SetXOPMessage

```
void
SetXOPMessage(message)
int message;                  // Message to pass to Igor during callback
```

Sets the message field of your XOP's IORecHandle.

This is used by XOPSupport routines during callbacks to Igor. You should not call it yourself.

Thread Safety

SetXOPMessage is not thread-safe.

GetXOPMessage

```
int
GetXOPMessage(void)
```

Returns the message field of your XOP's IORecHandle.

The message field contains the message that Igor is sending to your XOP. Your XOPEntry routine must call GetXOPMessage to find out what message Igor is sending.

NOTE: The message field is reused each time Igor calls your XOPEntry routine with a message or you call Igor back. Therefore, you must call GetXOPMessage before you do any callbacks to Igor. An easy mistake to make is to do an XOPNotice callback for debugging before you get the message. See **Messages, Arguments and Results** on page 65 for details.

Thread Safety

GetXOPMessage is not thread-safe.

GetXOPStatus

```
int
GetXOPStatus(void)
```

NOTE: This routine is obsolete and may be removed in a future version of the XOP Toolkit.

Returns the status field of your XOP's IORecHandle.

This is infrequently-used. It can tell you if Igor is in the background (not the active application).

See the discussion of status field under **The IORecHandle** on page 64.

Thread Safety

GetXOPStatus is not thread-safe.

GetXOPItem

```
XOPIORecParam
GetXOPItem(itemNumber)
int itemNumber;
```

Returns an item from the item list of XOP's IORec.

itemNumber is zero-based.

If itemNumber is greater than the number of items passed by Igor less one, GetXOPItem returns zero.

This is used by an XOP to get arguments associated with a message from Igor.

NOTE: The item list is reused each time Igor calls your XOPEntry routine with a message or you call Igor back. Therefore, if you need to get an item in response to a message from Igor, get it *before* you do *any* callbacks to Igor. An easy mistake to make is to do an XOPNotice callback for debugging before you get all of the arguments. See **Messages, Arguments and Results** on page 65 for details.

Thread Safety

GetXOPItem is not thread-safe.

Operation Handler Routines

XOPs implement external operations using Igor's Operation Handler as described in Chapter 5, **Adding Operations**. This section documents XOPSupport routines used in conjunction with Operation Handler.

RegisterOperation

```
int
RegisterOperation(cmdTemplate, runtimeNumVarList, runtimeStrVarList,
                     runtimeParamStructSize, runtimeAddress, options)
const char* cmdTemplate;          // Specifies operation's syntax
const char* runtimeNumVarList;    // List of numeric output variables
const char* runtimeStrVarList;    // List of string output variables
int runtimeParamStructSize;       // Size of runtime parameter structure
void* runtimeAddress;             // Address of operation Execute routine
int options;                      // Flags
```

Registers an XOP operation with Operation Handler.

cmdTemplate specifies the operation name and syntax.

runtimeNumVarList is a semicolon-separated list of numeric variables that the operation sets at runtime or NULL if it sets no numeric variables.

runtimeStrVarList is a semicolon-separated list of string variables that the operation sets at runtime or NULL if it sets no string variables.

runtimeParamStructSize is the size of the runtime parameter structure for the operation.

runtimeAddress is the address of the ExecuteOperation function for this operation.

The options parameter is kOperationIsThreadSafe for a thread-safe operation or 0 otherwise.

Returns 0 or an error code.

Example

```
char* cmdTemplate;          // From SimpleLoadWaveOperation.cpp
char* runtimeNumVarList;
char* runtimeStrVarList;

cmdTemplate = "SimpleLoadWave /A[=name:baseName] /D /I /N[=name:baseName] /O
                              /P=name:pathName /Q /W [string:fileParamStr]";
runtimeNumVarList = "V_flag;";
runtimeStrVarList = "S_path;S_fileName;S_waveNames;";
return RegisterOperation(cmdTemplate, runtimeNumVarList, runtimeStrVarList,
      sizeof(SimpleLoadWaveRuntimeParams), (void*)ExecuteSimpleLoadWave, 0);
```

Thread Safety

RegisterOperation is not thread-safe.

SetOperationNumVar

```
int
SetOperationNumVar(varName, dval)
const char* varName;        // C string containing name of variable
double dval;                // Value to store in variable
```

SetOperationNumVar is used only to implement an operation using Operation Handler. It is used to store a value in an external operation output numeric variable such as V_flag.

varName must be the name of a numeric variable that you specified via the runtimeNumVarList parameter to **RegisterOperation**.

dval is the value to be stored in the named variable.

If your operation was invoked from the command line, SetOperationNumVar sets a global variable in the current data folder, creating it if necessary.

If your operation was invoked from a macro, SetOperationNumVar sets a macro local variable.

If your operation was invoked from a user function, SetOperationNumVar sets a function local variable.

Returns 0 or an error code.

Example

```
SetOperationNumVar("V_VDT", number);   // From VDTOperations.cpp
```

Thread Safety

SetOperationNumVar is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

SetOperationStrVar

```
int
SetOperationStrVar(varName, str)
const char* varName;       // C string containing name of variable
const char* str;           // Value to store in variable
```

SetOperationStrVar is used only to implement an operation using Operation Handler. It is used to store a value in an external operation output string variable such as S_fileName.

varName must be the name of a string variable that you specified via the runtimeStrVarList parameter to **RegisterOperation**.

str is a null-terminated C string and points to the value to be stored in the named variable.

Use **SetOperationStrVar2** if your data is binary (may contain bytes whose value is zero other than the null terminator).

If your operation was invoked from the command line, SetOperationStrVar sets a global variable in the current data folder, creating it if necessary.

If your operation was invoked from a macro, SetOperationStrVar sets a macro local variable.

If your operation was invoked from a user function, SetOperationStrVar sets a local variable.

Returns 0 or an error code.

Thread Safety

SetOperationStrVar is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

SetOperationStrVar2

```
int
SetOperationStrVar2(varName, data, dataLength)
const char* varName;       // C string containing name of variable
const char* data;          // Value to store in variable
int dataLength;            // Length of data in bytes
```

SetOperationStrVar2 is just like **SetOperationStrVar** except for the dataLength parameter. Use SetOperationStrVar2 if the data is binary and may contain null bytes (bytes whose value is zero).

Thread Safety

SetOperationStrVar2 is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

VarNameToDataType

```
int
VarNameToDataType(varName, dataTypePtr)
const char* varName;    // Pointer to varName field in runtime param struct
int* dataTypePtr;       // Output: Data type of variable
```

This is used only to implement an operation using Operation Handler. It must be called only from your ExecuteOperation function.

This function is used only for operations which take the name of a variable as a parameter and then get or set the value of that variable. An example is Igor's Open operation which takes a "refNum" parameter and stores a value in the referenced variable.

After calling VarNameToDataType you would then call **FetchNumericDataUsingVarName**, **StoreNumericDataUsingVarName**, **FetchStringDataUsingVarName** or **StoreStringDataUsingVarName**.

varName must be a pointer to a varName field in your operation's runtime parameter structure when a pointer to this structure has been passed by Igor to your ExecuteOperation function. Igor relies on the varName field being set correctly (i.e., as Igor set it before calling your ExecuteOperation function). If your operation was called from a user function, the varName field will actually contain binary data used by Igor to access function local variables, NVARs and SVARs.

On output, *dataTypePtr will contain one of the following:

0	Means varName refers to a string variable or SVAR.
NT_FP64	Means varName refers to a scalar local variable or NVAR.
NT_FP64 | NT_CMPLX	Means varName refers to a complex local variable or NVAR.

Returns 0 or an error code.

See **VarName Parameters** on page 83 for further information.

Example

See VDTReadBinary.cpp.

Thread Safety

VarNameToDataType is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

FetchNumericDataUsingVarName

```
int
FetchNumericDataUsingVarName(varName, realPartPtr, imagPartPtr)
const char* varName;    // Pointer to varName field in runtime param struct
double* realPartPtr;
double* imagPartPtr;
```

Retrieves data from a numeric variable which may be local or global.

This is used only to implement an operation using Operation Handler. It must be called only from your ExecuteOperation function.

This function is used only for operations which take the name of a numeric variable as a parameter and then get the value of that variable.

varName must be a pointer to a varName field in your operation's runtime parameter structure when a pointer to this structure has been passed by Igor to your ExecuteOperation function. Igor relies on the varName field being set correctly (i.e., as Igor set it before calling your ExecuteOperation function). If your operation was called from a user function, the varName field will actually contain binary data used by Igor to access function local variables, NVARs and SVARs.

You should call this routine only after you have determined that varName refers to a numeric variable or NVAR. This will be the case if **VarNameToDataType** returns a non-zero number as the data type.

Returns 0 or an error code.

See **VarName Parameters** on page 83 for further information.

Thread Safety

FetchNumericDataUsingVarName is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

StoreNumericDataUsingVarName

```
int
StoreNumericDataUsingVarName(varName, realPart, imagPart)
const char* varName;    // Pointer to varName field in runtime param struct
double realPart;
double imagPart;
```

Stores data in a numeric variable which may be local or global.

This is used only to implement an operation using Operation Handler. It must be called only from your ExecuteOperation function.

This function is used only for operations which take the name of a numeric variable as a parameter and then set the value of that variable. An example is Igor's Open operation which takes a "refNum" parameter.

varName must be a pointer to a varName field in your operation's runtime parameter structure when a pointer to this structure has been passed by Igor to your ExecuteOperation function. Igor relies on the varName field being set correctly (i.e., as Igor set it before calling your ExecuteOperation function). If your operation was called from a user function, the varName field will actually contain binary data used by Igor to access function local variables, NVARs and SVARs.

You should call this routine only after you have determined that varName refers to a numeric variable or NVAR. This will be the case if **VarNameToDataType** returns a non-zero number as the data type.

Returns 0 or an error code.

See **VarName Parameters** on page 83 for further information.

Example

```
See VDTReadBinary.cpp.
```

Thread Safety

StoreNumericDataUsingVarName is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

FetchStringDataUsingVarName

```
int
FetchStringDataUsingVarName(varName, hPtr)
const char* varName;    // Pointer to varName field in runtime param struct
Handle* hPtr;           // Receives new handle containing string data
```

Retrieves data from a string variable which may be local or global.

Returns the string data via a new handle and stores the handle in *hPtr. On return, if *hPtr is not NULL then you own the new handle and must dispose it.

This is used only to implement an operation using Operation Handler. It must be called only from your ExecuteOperation function.

This function is used only for operations which take the name of a string variable as a parameter and then set the value of that variable.

varName must be a pointer to a varName field in your operation's runtime parameter structure when a pointer to this structure has been passed by Igor to your ExecuteOperation function. Igor relies on the varName field being set correctly (i.e., as Igor set it before calling your ExecuteOperation function). If your operation was called from a user function, the varName field will actually contain binary data used by Igor to access function local variables, NVARs and SVARs.

You should call this routine only after you have determined that varName refers to a string variable or SVAR. This will be the case if **VarNameToDataType** returns a zero as the data type.

Returns 0 or an error code.

See **VarName Parameters** on page 83 for further information.

Thread Safety

FetchStringDataUsingVarName is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

StoreStringDataUsingVarName

```
int
StoreStringDataUsingVarName(varName, buf, len)
const char* varName;    // Pointer to varName field in runtime param struct
const char* buf;        // String contents
BCInt len;              // Length of string
```

Stores data in a string variable which may be local or global.

This is used only to implement an operation using Operation Handler. It must be called only from your ExecuteOperation function.

This function is used only for operations which take the name of a string variable as a parameter and then set the value of that variable. An example is Igor's FReadLine operation which takes a "stringVarName" parameter.

varName must be a pointer to a varName field in your operation's runtime parameter structure when a pointer to this structure has been passed by Igor to your ExecuteOperation function. Igor relies on the varName field being set correctly (i.e., as Igor set it before calling your ExecuteOperation function). If your operation was called from a user function, the varName field will actually contain binary data used by Igor to access function local variables, NVARs and SVARs.

You should call this routine only after you have determined that varName refers to a string variable or SVAR. This will be the case if **VarNameToDataType** returns a zero as the data type.

Returns 0 or an error code.

See **VarName Parameters** on page 83 for further information.

Example

```
See VDTReadBinary.cpp.
```

Thread Safety

StoreStringDataUsingVarName is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

SetOperationWaveRef

```
int
SetOperationWaveRef(waveH, waveRefIndentifier)
waveHndl waveH;             // The destination wave you created.
int waveRefIndentifier;     // Tells Igor where local wave ref is stored.
```

Sets a wave reference in an Igor user-defined function to refer to a destination wave that your operation created.

This is used only to implement an operation using Igor's Operation Handler. It must be called only from your ExecuteOperation function.

This function is used only for operations which use a DataFolderAndName parameter (see **DataFolderAndName Parameters** on page 84) and declare it as a destination wave parameter using this kind of syntax in the operation template:

```
SampleOp DataFolderAndName:{dest,real}     // or complex or text
```

When you use this syntax and your operation is compiled in a user-defined function, the Igor function compiler may automatically create a wave reference in the function for the destination wave. However the automatically created wave reference will be NULL until you set it by calling SetOperationWaveRef.

The SetOperationWaveRef callback sets the automatically created wave reference to refer to a specific wave, namely the wave that you created in response to the DataFolderAndName parameter. You must call it after successfully creating the destination wave.

Igor will create an automatic wave reference only if the operation is called from a user-defined function and only if the destination wave is specified using a simple name (e.g., wave0 but not root:wave0 or $destWave). You have no way to know whether an automatic wave reference was created so you must call SetOperationWaveRef in all cases. SetOperationWaveRef will do nothing if no automatic wave reference exists.

The waveRefIndentifier parameter allows Igor to determine where in memory the wave reference is stored. This information is passed to your XOP in the "ParamSet" field of your ExecuteOperation structure. Your code should look something like this:

```
// In your RuntimeParams structure
DataFolderAndName dest;
int destParamsSet[1];

// In your ExecuteOperation function
waveH = NULL;
err = MDMakeWave(&waveH,p->dest.name,p->dest.dfH,dimSizes,type,overwrite);
if (waveH != NULL) {
   int waveRefIndentifier = p->destParamsSet[0];
   err = SetOperationWaveRef(waveH, waveRefIndentifier);
}
```

See **DataFolderAndName Destination Wave Example** on page 85 for a more complete example of using a DataFolderAndName parameter for an operation that creates a destination wave.

Returns 0 or an error code.

Thread Safety

SetOperationWaveRef is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

GetOperationWaveRef

```
int
GetOperationWaveRef(dfH, name, waveRefIdentifier, destWaveHPtr)
DataFolderHandle dfH;       // dfH field from DataFolderAndName structure
const char* name;           // name field from DataFolderAndName structure
int waveRefIdentifier;      // Value from destParamsSet field
waveHndl* destWaveHPtr;     // Output wave reference is stored here
```

Returns via destWaveHPtr a reference to the destination wave if it was specified using a wave reference or NULL otherwise.

NOTE: Except in rare cases, you should not call this function. Use **GetOperationDestWave** instead.

The GetOperationWaveRef routine supports the /DEST flag for an operation.

If the destination wave was specified by passing a wave reference to /DEST, this routine returns the wave handle via destWaveHPtr.

If the destination wave was not specified via a wave reference, this routine returns NULL via dest-WaveHPtr and you must create the destination wave yourself.

The rule is: If a simple name or the name of a structure wave field are passed to /DEST, the specified wave is returned via destWaveHPtr. If $<string> or a path are passed to /DEST, NULL is returned.

Here are typical cases where a wave reference specifies the destination wave:

```
SampleOp /DEST=jack
Wave w = root:jack
SampleOp /DEST=w
```

In these cases, GetOperationWaveRef would return a handle to wave jack via destWaveHPtr. In the first command, Operation Handler creates an automatic wave reference in the calling user-defined function.

Here are typical cases where a wave reference is not used to specify the destination wave:

```
String name = "jack"
SampleOp /DEST=$name        // Dest specified by $<string>
SampleOp /DEST=root:jack    // Dest specified by path
SampleOp /DEST=:jack        // Dest specified by path
```

In these cases, there is no wave reference for the destination wave and GetOperationWaveRef would return NULL via destWaveHPtr.

The user can specify that a wave reference be created by appending /WAVE after the /DEST flag, like this:

String name = "jack"

```
SampleOp /DEST=$name/WAVE=wDest
SampleOp /DEST=root:jack/WAVE=wDest
SampleOp /DEST=:jack/WAVE=wDest
```

"/WAVE=wDest" is an "inline WAVE reference statement". An inline WAVE reference does not determine which wave is the destination wave but merely provides a place for the operation to return a reference to the destination wave.

If a wave reference for the destination wave exists, it must be set to refer to the destination wave once that wave has been determined or created. You set the wave reference by calling **SetOperationWaveRef** later in the process.

See **GetOperationDestWave** for an example.

Thread Safety

GetOperationWaveRef is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

GetOperationDestWave

```
int
GetOperationDestWave(dfH, name, destWaveRefIdentifier, options,
               dimensionSizes, dataType, destWaveHPtr, destWaveCreatedPtr)
DataFolderHandle dfH;      // dfH field from DataFolderAndName structure
const char* name;          // name field from DataFolderAndName structure
int destWaveRefIdentifier; // Value from destParamsSet field
int options;               // Bit flags defined below
CountInt dimensionSizes[]; // Array of desired dest wave dimension sizes
int dataType;              // Desired dest wave data type
waveHndl* destWaveHPtr;    // Output: Wave reference is stored here
int* destWaveCreatedPtr;   // Output: Set to 1 if dest wave was created
```

Returns via destWaveHPtr a reference to the destination wave specified by the /DEST flag in an operation. GetOperationDestWave optionally creates the wave if it does not already exist. If the wave does exist, Get-OperationDestWave changes it as specified by the options parameter.

GetOperationDestWave is typically called to support the /DEST flag for an operation. It determines which wave is to be the destination wave, optionally creates it if it does not already exist, optionally overwrites it or sets its dimensions and data type if it does already exist, and returns the wave handle via dest-WaveHPtr.

GetOperationDestWave respects wave references passed as the destination wave when called from a user-defined function.

If GetOperationDestWave succeeds, it returns 0 as the function result and a non-NULL wave handle via destWaveHPtr. If it fails it returns a non-zero error code as the function result and NULL via dest-WaveHPtr. Possible errors include NOMEM, NO_TEXTNUMERIC_WAVE_OVERWRITE, and NAME_WAV_CONFLICT (the destination wave already exists and overwrite is not specified).

destWaveRefIdentifier is used by GetOperationDestWave to access a user-defined function local wave ref-erence for the destination wave, if such a wave reference was specified with the /DEST flag. The example below shows how to obtain destWaveRefIdentifier from the operation's runtime parameter structure.

The options parameter is a bitwise combination of the following flags:

Flag	Description
kOpDestWaveOverwriteOK	Permits returning a pre-existing wave. If kOpDestWaveOverwriteOK is omitted and the wave specified by /DEST already exists, GetOperationDestWave returns an error.
kOpDestWaveChangeExistingWave	If the destination wave already exists its dimensions and data type are changed based on the dimensionSizes and dataType parameters but other properties (units, dimension scaling, dimension labels, wave note) are left unchanged.
kOpDestWaveOverwriteExistingWave	If the destination wave already exists it is overwritten using the specified dimension sizes and data type. The overwritten wave's properties (units, dimension scaling, dimension labels, wave note) are set to default values. Its data is left as is and you should treat it as uninitialized.
kOpDestWaveMakeFreeWave	Destination wave will be a new free wave.
kOpDestWaveMustAlreadyExist	Destination wave must already exist. Otherwise an error is returned.

The choice between kOpDestWaveChangeExistingWave and kOpDestWaveOverwriteExistingWave must be made on a case-by-case basis. If you are converting an existing operation to use GetOperationDestWave you should choose between kOpDestWaveChangeExistingWave and kOpDestWaveOverwriteExisting-

Wave so that the behavior of your operation will not change. For most new applications, kOpDestWaveOverwriteExistingWave is preferrable since it makes the output of the operation independent of pre-existing conditions.

If kOpDestWaveChangeExistingWave and kOpDestWaveOverwriteExistingWave are both cleared, then GetOperationDestWave will not change the dimensions and data type of a pre-existing destination wave. In this case, it is up to you to make sure that the dimensions and data type of the returned wave are appropriate and change them if necessary.

If kOpDestWaveChangeExistingWave and kOpDestWaveOverwriteExistingWave are both set, this is a programmer error and an error is returned.

If your operation has a /FREE flag, signifying that the destination wave should be a free wave, set the kOpDestWaveMakeFreeWave bit. If kOpDestWaveMakeFreeWave is set, GetOperationDestWave makes a new free wave as the destination wave and returns it via destWaveHPtr and all other option flag are ignored. See **Free Waves** on page 135 for further details on free waves.

If kOpDestWaveMakeFreeWave is not set, this procedure is followed: If the destination wave was specified via a wave reference by the calling user-defined function, GetOperationDestWave returns that wave via destWaveHPtr. Otherwise it looks for an existing wave specified by dfH and name. If there is an existing wave, GetOperationDestWave reuses it. Otherwise it creates a new wave using dfH and name. The rules for obtaining the destination wave via a wave reference are explained in the documentation for **GetOperationWaveRef**.

If kOpDestWaveMustAlreadyExist is set, then, if the destination wave does not already exist, the NOWAV ("expected wave name") error is returned. You may want to test for NOWAV and return a more specific error code. If you set kOpDestWaveMustAlreadyExist you must also set kOpDestWaveOverwriteOK because if kOpDestWaveOverwriteOK is cleared GetOperationDestWave returns an error if the destination wave exists.

If you want to return an existing wave only without overwriting or changing it, pass (kOpDestWaveMustAlreadyExist | kOpDestWaveOverwriteOK) and leave all other bits cleared.

dimensionSizes is an array of wave dimension sizes as shown in the example below. If kOpDestWaveMustAlreadyExist is set and kOpDestWaveChangeExistingWave, kOpDestWaveOverwriteExistingWave and kOpDestWaveMakeFreeWave are cleared then dimensionSizes is not used and you can pass NULL.

dataType is normally a standard Igor data type (e.g., NT_FP64, (NT_FP32 | NT_CMPLX), TEXT_WAVE_TYPE). However, if you pass NULL for dimensionSizes, you must pass -1 for dataType indicating that you do not want to change the data type.

If destWaveCreatedPtr is not NULL, *destWaveCreatedPtr is set to 1 if GetOperationDestWave created a new wave or to 0 if GetOperationDestWave reused an existing wave.

In the following example, the operation is defined by this Operation Handler syntax:

```
SampleOp /DEST=DataFolderAndName:{dest,real}
```

This results in an operation runtime parameter structure containing:

```
int DESTFlagEncountered;
DataFolderAndName dest;
int DESTFlagParamsSet[1];
```

Here is typical usage for an operation with a /DEST flag. In this example, p is a pointer to the operation runtime parameter structure:

```
waveHndl destWaveH;         // Destination wave handle.
int destWaveRefIdentifier;
char destWaveName[MAX_OBJ_NAME+1];
DataFolderHandle dfH;
int dataType;
CountInt dimensionSizes[MAX_DIMENSIONS+1];
int destWaveCreated;
int options;
```

```
   int err;

   destWaveH = NULL;
   destWaveRefIdentifier = 0;

   strcpy(destWaveName, "W_SampleOp");    // Default dest wave name
   dfH = NULL;                            // Default is current data folder
   dataType = NT_FP64;
   MemClear(dimensionSizes, sizeof(dimensionSizes));
   dimensionSizes[ROWS] = 100;
   if (p->DESTFlagEncountered) {
      strcpy(destWaveName, p->dest.name);
      dfH = p->dest.dfH;
      // If a wave reference was used, p->destParamsSet[0] contains info that
      // GetOperationDestWave uses to find the address of the wave reference.
      destWaveRefIdentifier = p->DESTFlagParamsSet[0];
   }

   options = kOpDestWaveOverwriteOK | kOpDestWaveOverwriteExistingWave;
   err = GetOperationDestWave(dfH, destWaveName, destWaveRefIdentifier,
            options, dimensionSizes, dataType, &destWaveH, &destWaveCreated);
   if (err != 0)
      return err;

   <Store output data in dest wave>
   WaveHandleModified(destWaveH);

   // Set wave reference to refer to destination wave.
   if (destWaveRefIdentifier != 0)
      SetOperationWaveRef(destWaveH, destWaveRefIdentifier);
```

The call to SetOperationWaveRef sets the automatic destination wave reference created by Operation Handler when you use the DataFolderAndName syntax shown above in your operation template.

Thread Safety

GetOperationDestWave is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

Routines for Accessing Waves

These routines allow you to create, change, kill or access information about waves. Some require that you pass the wave's name. Others require that you pass a handle to the wave's data structure (a waveHndl). You receive this handle as a parameter to an external operation or function or get it using the **FetchWave**, **MakeWave**, **MDMakeWave**, **GetDataFolderObject** or **FetchWaveFromDataFolder** callbacks.

So that your XOP will work with current and future versions of Igor, it must not access the contents of wave handles directly but instead must use the routines in this section. Also, wave handles belong to Igor and your XOP must not delete or directly modify them.

Igor Pro 3.0 added multi-dimensional waves, up to four dimensions, as well as waves containing text rather than numbers. To support this, we added a number of XOPSupport routines to the XOP Toolkit. The added routines have names that start with "MD" (e.g., MDMakeWave). These routines have several purposes:

- To get and set multi-dimensional wave properties such as units, scaling and dimension labels.
- To get and set multi-dimensional wave data values, text as well as numeric.
- To provide faster access to wave information than previous XOPSupport routines provided.

All of the old wave access routines will continue to work with all supported versions of Igor. However, for new programming, we recommend that you use the new wave access routines.

The symbols ROWS, COLUMNS, LAYERS and CHUNKS are defined in IgorXOP.h as 0, 1, 2 and 3 respectively. These symbols are often used to index into an array of dimension sizes or wave element indices.

All of the wave access routines are defined in the file XOPWaveAccess.c.

The WaveAccess sample XOP contains examples that illustrate most of the wave access techniques.

In the following list of wave access routines, the older routines are listed first, followed by the newer, multi-dimensional-aware routines.

MakeWave

```
int
MakeWave(waveHandlePtr, waveName, numPoints, type, overwrite)
waveHndl* waveHandlePtr;    // Place to put waveHndl for new wave
char* waveName;             // C string containing name of Igor wave
CountInt numPoints;         // Desired length of wave
int type;                   // Numeric type (e.g., NT_FP32, NT_FP64)
int overwrite;              // If non-zero, overwrites existing wave
```

Creates a 1D wave with the specified name, number of points, and numeric type.

NOTE: For historical reasons, if numPoints is zero, MakeWave creates a 128-point wave. To create a zero-point wave, use **MDMakeWave**.

If successful, it returns 0 as the function result and puts a waveHndl for the new wave in *waveHandlePtr.

If unsuccessful, it returns an Igor error code as the function result.

Prior to XOP Toolkit 6, if the numPoints parameter was zero, the wave was created with 128 points. This behavior was a relic of a time when Igor required that a wave contain at least two points (prior to Igor Pro 3.0). Now when numPoints is zero, a zero-point wave is created.

type is one of the following:

Type	Wave Element Contains
NT_FP32	32 bit floating-point
NT_FP64	64 bit floating-point

Type	Wave Element Contains
NT_I8	8 bit signed integer
NT_I16	16 bit signed integer
NT_I32	32 bit signed integer
NT_I64	64 bit signed integer
NT_I8 | NT_UNSIGNED	8 bit unsigned integer
NT_I16 | NT_UNSIGNED	16 bit unsigned integer
NT_I32 | NT_UNSIGNED	32 bit unsigned integer
NT_I64 | NT_UNSIGNED	64 bit unsigned integer
TEXT_WAVE_TYPE	Text (string data)
WAVE_TYPE	Wave handle or NULL
DATAFOLDER_TYPE	Data folder handle or NULL

To make a complex numeric wave, OR with NT_CMPLX, for example (NT_FP64 | NT_CMPLX). Any numeric wave can be complex. Text waves, wave reference waves and data folder reference waves can not be complex.

Igor can not overwrite a text wave with a numeric wave or vice-versa and you will receive an error if you attempt to do this.

It is recommended that you use the integer types only to store raw data that you have acquired and when economical storage is a high priority, such as when storing images or other large data sets. The reason for this is that Igor needs to translate integer wave data into floating point for display, analysis or just about any other purpose.

NOTE: The block of memory referenced by the wave handle can be relocated if you increase the size of an existing wave. To avoid dangling pointer bugs, see the discussion of dangling pointers under **The Direct Access Method** on page 126.

Thread Safety

MakeWave is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

ChangeWave

```
int
ChangeWave(waveHandle, numPoints, type)
waveHndl waveHandle;       // WaveHndl for wave to change
CountInt numPoints;        // Desired new length of wave
int type;                  // Data type (e.g., NT_FP32, NT_FP64)
```

Changes the 1D wave to the desired length and data type.

Igor can not change a text wave into a numeric wave or vice-versa and you will receive an error if you attempt to do this.

The function result is 0 if successful or an Igor error code otherwise.

NOTE: The block of memory referenced by the wave handle can be relocated if you increase the size of the wave. To avoid dangling pointer bugs, see the discussion of dangling pointers under **The Direct Access Method** on page 126.

Thread Safety

ChangeWave is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

KillWave

```
int
KillWave(waveHandle)
waveHndl waveHandle;        // waveHndl for wave to kill
```

Kills the specified wave.

The function result is 0 if successful or an Igor error code otherwise.

A wave is in use and can't be killed if it is used in a graph, table or dependency formula. An XOP can also prevent a wave used in the main Igor thread from being killed by responding to the OBJINUSE message.

For information on a related technique useful in preemptive Igor threads, see **Wave Reference Counting** on page 131.

Thread Safety

KillWave is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

FetchWave

```
waveHndl
FetchWave(waveName)
char* waveName;             // C string containing name of Igor wave
```

Returns a handle to the data structure for the named wave in the current data folder or NULL if the wave does not exist.

Be sure to check the wave's type, using **WaveType**, and return an error if you receive a wave as a parameter whose type you can't handle. You may also want to check the dimensionality of the wave using **MDGetWaveDimensions**.

To support data folders, modern XOPs must use **FetchWaveFromDataFolder** instead of FetchWave.

Thread Safety

FetchWave is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

FetchWaveFromDataFolder

```
waveHndl
FetchWaveFromDataFolder(dataFolderH, waveName)
DataFolderHandle dataFolderH;
char* waveName;
```

FetchWaveFromDataFolder returns a handle to the specified wave in the specified data folder or NULL if the wave does not exist.

If dataFolderH is NULL, it uses the current data folder.

Be sure to check the wave's type, using **WaveType**, and return an error if you receive a wave as a parameter whose type you can't handle. You may also want to check the dimensionality of the wave using **MDGetWaveDimensions**.

Thread Safety

FetchWaveFromDataFolder is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

WaveType

```
int
WaveType(waveHandle)
waveHndl waveHandle;        // Handle to wave's data structure
```

Returns the wave's data type.

The returned value is one of the following except that, if the wave is complex, the NT_CMPLX bit will be set:

Type	Wave Element Contains
NT_FP32	32 bit floating-point
NT_FP64	64 bit floating-point
NT_I8	8 bit signed integer
NT_I16	16 bit signed integer
NT_I32	32 bit signed integer
NT_I64	64 bit signed integer
NT_I8 | NT_UNSIGNED	8 bit unsigned integer
NT_I16 | NT_UNSIGNED	16 bit unsigned integer
NT_I32 | NT_UNSIGNED	32 bit unsigned integer
NT_I64 | NT_UNSIGNED	64 bit unsigned integer
TEXT_WAVE_TYPE	Text (string data)
WAVE_TYPE	Wave handle or NULL
DATAFOLDER_TYPE	Data folder handle or NULL

NOTE: Future versions of Igor may support other data types. You should make sure that you can handle the type of wave you receive as a parameter in an operation or function and generate an error if you receive a wave type you can't handle.

Thread Safety

WaveType is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

WavePoints

```
CountInt
WavePoints(waveHandle)
waveHndl waveHandle;        // Handle to wave's data structure
```

Returns the number of points in the wave.

If the wave is multi-dimensional, this is the number of elements in all dimensions. To find the number of elements in each dimension separately, use **MDGetWaveDimensions**.

Thread Safety

WavePoints is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

WaveModDate

```
TickCountInt
WaveModDate(waveHandle)
waveHndl waveHandle;        // Handle to wave's data structure
```

Returns wave modification date. This is an unsigned 32-bit number in Igor date/time format, namely the number of seconds since midnight, January 1, 1904.

The mod date has a resolution of one second.

Modification date tracking was added to Igor in Igor 1.2. If a wave is loaded from a file created by an older version of Igor, the mod date field will be zero and this routine will return zero.

Thread Safety

WaveModDate is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

WaveModCount

```
int
WaveModCount(waveHandle)
waveHndl waveHandle;        // Handle to wave's data structure
```

Returns a value that can be used to tell if a wave has been changed between one call to WaveModCount and another.

The exact value returned by WaveModCount has no significance. The only valid use for it is to compare the values returned by two calls to WaveModCount. If they are the different, the wave was changed in the interim.

Example

```
waveModCount1 = WaveModCount(waveH);
. . .
waveModCount2 = WaveModCount(waveH);
if (waveModCount2 != waveModCount1)
   // Wave has changed.
```

Thread Safety

WaveModCount is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

WaveModState

```
int
WaveModState(waveHandle)
waveHndl waveHandle;        // Handle to wave's data structure
```

Returns the truth that the wave has been modified since the last save to disk.

Thread Safety

WaveModState is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

WaveLock

```
int
WaveLock(waveHandle)
waveHndl waveHandle;       // Handle to wave's data structure
```

Returns the lock state of the wave.

A return value of 0 signifies that the wave is not locked.

A return value of 1 signifies that the wave is locked. In that case, you should not kill the wave or modify it in any way.

Thread Safety

WaveLock is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

SetWaveLock

```
int
SetWaveLock(waveHandle, lockState)
waveHndl waveHandle;       // Handle to wave's data structure
int lockState;             // 0 or 1
```

Sets wave's lock state. If lockState is 0, the wave will be unlocked. If it is 1, the wave will be locked. All other bits are reserved.

Returns the previous state of the wave lock setting.

Thread Safety

SetWaveLock is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

WaveScaling

```
void
WaveScaling(waveHandle, dxPtr, x0Ptr, topPtr, botPtr)
waveHndl waveHandle;       // Handle to wave's data structure
double *dxPtr, *x0Ptr, *topPtr, *botPtr;
```

Returns the wave’s X and data scaling information.

Igor calculates the X value for point p of the wave as:

X value = x0 + dx*p

top and bottom are the values user entered for the wave’s data full scale.

If both are zero then there is no data full scale for this wave.

New XOPs should use **MDGetWaveScaling** instead of WaveScaling so that they can access scaling for higher dimensions.

Thread Safety

WaveScaling is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

SetWaveScaling

```
void
SetWaveScaling(waveHandle, dxPtr, x0Ptr, topPtr, botPtr)
waveHndl waveHandle;       // Handle to wave's data structure
double *dxPtr, *x0Ptr, *topPtr, *botPtr;
```

Sets the X scaling and data full scale for the specified wave.

If either dxPtr or x0Ptr is NULL, the X scaling is not set. Otherwise, Igor sets the X scaling of the wave. This is the same setting as is set by the “SetScale/P x” operation from within Igor. Igor calculates the X value for point p of the wave as:

```
X value = x0 + dx*p
```

If either topPtr or botPtr is NULL, the data full-scale is not set. Otherwise, Igor sets the data full scale of the wave. This is the same setting as is set by the “SetScale d” operation from within Igor. This setting is used only for documentation purposes. For example, if data was acquired on a -10 to 10 volt range, you would set the data full scale to (-10, 10).

New XOPs should use **MDSetWaveScaling** instead of SetWaveScaling so that they can access scaling for higher dimensions.

Thread Safety

SetWaveScaling is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

WaveUnits

```
void
WaveUnits(waveHandle, xUnits, yUnits)
waveHndl waveHandle;       // Handle to wave's data structure
char* xUnits;              // C string defining wave's X units
char* dataUnits;           // C string defining wave's data units
```

Returns the wave’s X and data units.

The units are strings like “kg”, “m”, or “s”, or “” for no units.

In Igor Pro 3.0, the number of characters allowed was increased from 3 to 49 (MAX_UNIT_CHARS). For backward compatibility, WaveUnits will return no more than 3 characters (plus the null terminator). To get the full units and to access units for higher dimensions, new XOPs should use **MDGetWaveUnits** instead of WaveUnits.

Thread Safety

WaveUnits is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

SetWaveUnits

```
void
SetWaveUnits(waveHandle, xUnits, yUnits)
waveHndl waveHandle;        // Handle to wave's data structure
char* xUnits;               // C string defining wave's X units
char* dataUnits;            // C string defining wave's data units
```

Sets the wave's X and data units.

The units are strings like "kg", "m", or "s", or "" for no units.

If xUnits is NULL the X units are not set.

If dataUnits is NULL, the data units are not set.

Units can be up to 49 (MAX_UNIT_CHARS) characters long.

New XOPs should use **MDSetWaveUnits** instead of SetWaveUnits so that they can access units for higher dimensions.

Thread Safety

SetWaveUnits is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

WaveNoteCopy

```
Handle
WaveNoteCopy(waveHandle)
waveHndl waveHandle;        // Handle to wave's data structure
```

Returns a handle containing the wave's note text or NULL if the wave has no wave note.

The returned handle is a copy of Igor's internal wave note handle. You own the returned handle and, if it is not NULL, you must dispose it using WMDisposeHandle.

Note that the text in the handle is *not* null terminated. Use **WMGetHandleSize** to find the number of bytes in the handle. To use C string functions on this text you need to copy it to a local buffer and null-terminate it or add a null terminator to the handle and remove the null terminator when you are done. See **Understand the Difference Between a String in a Handle and a C String** on page 221.

If you want to change the wave's note, use the **SetWaveNote** callback.

WaveNoteCopy is a replacement for the WaveNote routine from XOP Toolkit 6 and before. If you used WaveNote, change the call to WaveNoteCopy and, if the returned handle is not NULL, dispose the handle when you are finished using it.

Thread Safety

WaveNoteCopy is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

SetWaveNote

```
void
SetWaveNote(waveHandle, noteHandle)
waveHndl waveHandle;        // Handle to wave's data structure
Handle noteHandle;          // Handle to the text for the wave's note
```

Sets the wave's note.

noteHandle is a handle to plain text with lines separated by carriage returns (ASCII 13) and with no null termination at the end. Once you pass the noteHandle to Igor it belongs to Igor so don't modify or dispose of it. This should be a handle that you created in your XOP using the **WMNewHandle** or **WMHandTo-Hand**, not a handle you got from Igor.

If noteHandle is NULL the note is set to empty.

Thread Safety

SetWaveNote is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

WaveName

```
void
WaveName(waveHandle, name)
waveHndl waveHandle;        // Handle to wave's data structure
char name[MAX_OBJ_NAME+1]; // C string to receive name
```

Puts the wave's name in the string identified by namePtr.

Thread Safety

WaveName is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

WaveTextEncoding

```
int
WaveTextEncoding(waveH, element, getEffectiveTextEncoding, tecPtr)
waveHndl waveH;
int element;
int getEffectiveTextEncoding;
int* tecPtr;
```

Returns via tecPtr a WMTextEncodingCode that identifies the text encoding of the stored text associated with the part of a wave identified by element.

WMTextEncodingCode is an enum defined in IgorXOP.h.

element is one of the following:

Value	Wave Element
1	Wave name
2	Wave units
4	Wave note
8	Wave dimension labels
16	Text wave contents

If getEffectiveTextEncoding is 1, WaveTextEncoding returns the effective wave text encoding. Otherwise it returns the raw wave text encoding. See the help for the built-in Igor7 WaveTextEncoding function for an explanation of this distinction.

The values returned via tecPtr are described in the documentation for the built-in Igor WaveTextEncoding function in Igor Pro 7. The most common values are:

WMTextEncodingCode	Description
kWMTextEncodingUTF8	UTF-8
kWMTextEncodingMacRoman	MacRoman (Macintosh western European)
kWMTextEncodingWindows1252	Windows-1252 (Windows western European)
kWMTextEncodingJIS	Shift-JIS (Japanese)
kWMTextEncodingBinary	

kWMTextEncodingBinary is not a real text encoding code but rather indicates that the wave contains binary data rather than text data.

Because nearly all XOPSupport routines, when running with Igor7, require text parameters to be UTF-8 and return output text as UTF-8, most XOPs will not need to use this routine.

See the **Text Encodings** on page 185 and the documentation for the built-in Igor7 WaveTextEncoding function for further information.

Added for Igor Pro 7.00. If you call this with an earlier version of Igor, it will return IGOR_OBSOLETE and do nothing.

Thread Safety

WaveTextEncoding is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

WaveData

```
void*
WaveData(waveHandle)
waveHndl waveHandle;       // Handle to wave's data structure
```

Returns pointer to the start of wave's data.

NOTE: The pointer is only valid if the block of memory containing the wave's data is not resized. To avoid dangling pointer bugs, see the discussion of dangling pointers under **The Direct Access Method** on page 126.

See Chapter 7 for detailed instructions on accessing wave data.

Thread Safety

WaveData is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

WaveMemorySize

```
BCInt
WaveMemorySize(waveH, which)
waveHndl waveH;            // Wave handle
int which;                 // Code for what information you want
```

Most XOPs will not need to use this routine.

In Igor Pro 6 and before, wave handles were regular handles. Although there was little reason to do so, you could call WMGetHandleSize on them and get a correct answer.

In Igor Pro 7, to support 64 bits on Macintosh, WaveMetrics had to change the way a wave's data was allocated. As a result, a wave handle is no longer a regular handle. Calling WMGetHandleSize on it will return the wrong result or crash.

This routine provides a way to get information about the memory used by a wave that will work in Igor Pro 7 as well as in earlier versions.

which is defined as follows:

Value	Information Returned
0	The size in bytes of the wave handle itself.
1	The size in bytes of the wave header (a structure located at the start of the wave handle).
2	The size in bytes of the wave numeric or text data.
3	The size in bytes of the wave handle and the numeric or text data.
4	In Igor Pro 7 or later, the total number of bytes required to store all wave data. This includes memory used to store wave properties such as the wave note, units and dimension labels. In Igor Pro 6 or before which=4 returns the same value as which=3 - the size in bytes of the wave handle and the numeric or text data.

which=2, 3 and 4 include the size of numeric data for numeric a wave and the size of text data for a text wave.

which=4 returns the most accurate assessment of the total memory usage of the wave. This is because, in Igor Pro 7 and later, it includes wave property data and also because, in some cases as explained below, the data for text waves is stored in separate objects, not in the wave handle itself.

In Igor Pro 7, the size of the wave handle itself may not accurately reflect the amount of memory required by a text wave. This is because, in most cases, Igor Pro 7 stores the text data for each element in a separate text element object and stores pointers to the text element objects in the wave handle itself. Thus the size of the wave handle itself reflects the storage needed for the pointers, not the storage needed for the actual text.

In Igor Pro 7 and later, determining the size of text data for a large text wave, using which=2, which=3 or which=4, can be time-consuming. This is because, in most cases, Igor Pro 7 stores the data for each element of the wave in a separate text element object and stores pointers to the text element objects in the wave handle itself. Thus Igor must determine the sum of the sizes of each of the objects.

Thread Safety

WaveMemorySize is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

CalcWaveRange

```
int*
CalcWaveRange(wrp)
WaveRangeRecPtr wrp;
```

Given coordinates expressed in point numbers or X values, CalcWaveRange returns the corresponding range of point numbers within the wave.

wrp is a pointer to a WaveRangeRec structure defined in IgorXOP.h.

See **Wave Range Parameters** on page 82 for an example.

Returns 0 if OK or a non-zero error code.

Thread Safety

CalcWaveRange is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

WaveHandleModified

```
void
WaveHandleModified(waveHandle)
waveHndl waveHandle;       // Handle to wave's data structure
```

Informs Igor that your XOP modified the specified wave.

At the time of the next update, Igor will update any windows that display the wave.

Thread Safety

WaveHandleModified is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

WaveModified

```
void
WaveModified(waveName)
char* waveName;            // C string containing wave's name
```

NOTE: This routine is obsolete and may be removed in a future version of the XOP Toolkit. Use **WaveHandleModified** instead.

Informs Igor that your XOP modified the wave referred to by waveName in the current data folder.

So that your XOP will not depend on the current data folder, you should use **WaveHandleModified** instead of WaveModified.

Thread Safety

WaveModified is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

MDMakeWave

```
int
MDMakeWave(waveHPtr,waveName,dataFolderH,dimensionSizes,type,overwrite)
waveHndl* waveHPtr;           // Place to put waveHndl for new wave
char* waveName;               // C string containing name of Igor wave
DataFolderHandle dataFolderH; // Handle to data folder or NULL.
CountInt dimensionSizes[MAX_DIMENSIONS+1];   // Array of dimension sizes
int type;                     // Data type for new wave
int overwrite;                // If non-zero, overwrites existing wave
```

Makes a wave with the specified name, type and dimension sizes in the specified data folder.

If dataFolderH is NULL, it uses the current folder.

type is one of the following:

Type	Wave Element Contains
NT_FP32	32 bit floating-point
NT_FP64	64 bit floating-point

Type	Wave Element Contains
NT_I8	8 bit signed integer
NT_I16	16 bit signed integer
NT_I32	32 bit signed integer
NT_I64	64 bit signed integer
NT_I8 | NT_UNSIGNED	8 bit unsigned integer
NT_I16 | NT_UNSIGNED	16 bit unsigned integer
NT_I32 | NT_UNSIGNED	32 bit unsigned integer
NT_I64 | NT_UNSIGNED	64 bit unsigned integer
TEXT_WAVE_TYPE	Text (string data)
WAVE_TYPE	Wave handle or NULL
DATAFOLDER_TYPE	Data folder handle or NULL

To make a complex numeric wave, OR with NT_CMPLX, for example (NT_FP64 | NT_CMPLX). Any numeric wave can be complex. Text waves, wave reference waves and data folder reference waves can not be complex.

If overwrite is non-zero, an existing wave with the same name will be overwritten.

Igor can not overwrite a text wave with a numeric wave or vice-versa and you will receive an error if you attempt to do this.

If overwrite is zero and a wave of the specified name exists, MDMakeWave will return a non-zero error code result.

For each dimension, dimensionSizes[i] specifies the number of elements in that dimension. For a wave of dimension n, i goes from 0 to n-1.

NOTE: dimensionSizes[n] must be zero. This is how Igor determines how many dimensions the wave is to have.

Igor supports a maximum of four dimensions. Therefore, dimSizes[n] must be zero, where n is less than or equal to four. MAX_DIMENSIONS is larger than 4 to allow XOPs to continue to work in the event that a future version of Igor supports more than four dimensions.

You can pass -1 for dataFolderH to create a free wave. This would be appropriate if, for example, your external function were called from a user-defined function with a flag parameter indicating that the user wants to create a free wave. When making a free wave, the overwrite parameter is irrelevant and is ignored. You can also create a free wave using **GetOperationDestWave**. See **Free Waves** on page 135 for further details on free waves.

Returns error code or 0 if wave was made.

NOTE: The block of memory referenced by the wave handle can be relocated if you increase the size of an existing wave. To avoid dangling pointer bugs, see the discussion of dangling pointers under **The Direct Access Method** on page 126.

Example

```
waveHndl waveH;
char waveName[MAX_OBJ_NAME+1];
CountInt dimensionSizes[MAX_DIMENSIONS+1];
int result;

strcpy(waveName, "Wave3D");
dimensionSizes[0] = 10;    // 10 rows
```

```
dimensionSizes[1] = 10;     // 10 columns
dimensionSizes[2] = 10;     // 10 layers
dimensionSizes[3] = 0;      // 0 marks first unused dimension
if (result = MDMakeWave(&waveH, waveName, NULL, dimensionSizes, NT_FP64, 1))
   return result;
```

Thread Safety

MDMakeWave is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

MDGetWaveDimensions

```
int
MDGetWaveDimensions(waveH, numDimensionsPtr, dimensionSizes)
waveHndl waveH;               // Handle to the wave of interest
int* numDimensionsPtr;        // Number of dimensions in the wave
CountInt dimensionSizes[MAX_DIMENSIONS+1];   // Array of dimension sizes
```

Returns the number of used dimensions in wave via numDimensionsPtr and the number of points in each used dimension via dimensionSizes.

If you only want to know the number of dimensions, you can pass NULL for dimensionSizes.

NOTE: dimensionSizes (if not NULL) should have room for MAX_DIMENSIONS+1 values.

For an n dimensional wave, MDGetWaveDimensions sets dimensionSizes[0..n-1] to the number of elements in the corresponding dimension and sets dimensionSizes[n..MAX_DIMENSIONS] to zero, indicating that they are unused dimensions. This guarantees that there will always be an element containing zero in the dimensionSizes array.

The function result is 0 or an Igor error code.

Example

```
int numDimensions;
CountInt dimensionSizes[MAX_DIMENSIONS+1];
int result;

if (result = MDGetWaveDimensions(waveH, &numDimensions, dimensionSizes))
   return result;
```

Thread Safety

MDGetWaveDimensions is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

MDChangeWave

```
int
MDChangeWave(waveH, dataType, dimensionSizes)
waveHndl waveH;            // Handle to the wave of interest
int dataType;              // New numeric type or -1 for no change
CountInt dimensionSizes[MAX_DIMENSIONS+1];   // Array of new dimension sizes
```

Changes one or more of the following:

The wave's data type

The number of dimensions in the wave

The number of points in one or more dimensions dataType is one of the following:

-1 for no change in data type

One of the data types listed for the **MakeWave** XOPSupport routine

For numeric waves, the data types may be ORed with NT_COMPLEX to make the wave complex. Text waves, wave reference waves and data folder reference waves can not be complex.

Igor can not convert a text wave to a numeric wave or vice-versa and you will receive an error if you attempt to do this.

dimensionSizes[i] contains the desired number of points for dimension i.

For a wave with n dimensions, dimensionSizes[n] must be zero. Then the size of each dimension is set by dimensionSizes[0..n-1]. If dimensionSizes[i] == -1, then the size of dimension i will be unchanged.

Igor supports a maximum of four dimensions. Therefore, dimSizes[n] must be zero, where n is less than or equal to four. MAX_DIMENSIONS is larger than 4 to allow XOPs to continue to work in the event that a future version of Igor supports more than four dimensions.

The function result is 0 or an error code.

NOTE: The block of memory referenced by the wave handle can be relocated if you increase the size of the wave. To avoid dangling pointer bugs, see the discussion of dangling pointers under **The Direct Access Method** on page 126.

Example

```
int dataType;
CountInt dimensionSizes[MAX_DIMENSIONS+1];
int result;

// Clear all dimensions sizes to avoid undefined values.
MemClear(dimensionSizes, sizeof(dimensionSizes));
dimensionSizes[0] = 10;     // 10 rows
dimensionSizes[1] = 10;     // 10 columns
dimensionSizes[2] = 10;     // 10 layers
dimensionSizes[3] = 0;      // 0 marks first unused dimension
dataType = NT_FP64 | NT_CMPLX;   // complex, double-precision
if (result = MDChangeWave(waveH, dataType, dimensionSizes))
   return result;
```

Thread Safety

MDChangeWave is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

MDChangeWave2

```
int
MDChangeWave2(waveH, dataType, dimensionSizes, mode)
waveHndl waveH;            // Handle to the wave of interest
int dataType;              // New numeric type or -1 for no change
CountInt dimensionSizes[MAX_DIMENSIONS+1];   // Array of new dimension sizes
int mode;
```

This is the same as MDChangeWave except for the added mode parameter.

Mode	Data Format
Mode=0	Does a normal redimension.
Mode=1	Changes the wave's dimensions without changing the wave data. This is useful, for example, when you have a 2D wave consisting of 5 rows and 3 columns which you want to treat as a 2D wave consisting of 3 rows and 5 columns or if you have loaded floating point data into an unsigned byte wave.
Mode=2	Changes the wave data from big-endian to little-endian or vice versa. This is useful when you have loaded data from a file that uses a byte ordering different from that of the platform on which you are running.

Returns 0 or an error code.

See **MDChangeWave** for further discussion.

NOTE: The block of memory referenced by the wave handle can be relocated if you increase the size of the wave. To avoid dangling pointer bugs, see the discussion of dangling pointers under **The Direct Access Method** on page 126.

Thread Safety

MDChangeWave2 is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

MDGetWaveScaling

```
int
MDGetWaveScaling(waveH, dimension, sfAPtr, sfBPtr)
waveHndl waveH;            // Handle to the wave of interest
int dimension;
double* sfAPtr;            // Delta value goes here
double* sfBPtr;            // Offset value goes here
```

Returns the dimension scaling values or the data full scale values for the wave via sfAPtr and sfBPtr. If dimension is -1, it returns the data full scale values. Otherwise, it returns the dimension scaling for the specified dimension.

For dimension i (i=0 to 3), the scaled index for element e is:

```
<scaled index> = sfA[i]*e + sfB[i]
```

If dimension is -1, this gets the wave’s data full scale setting instead of dimension scaling. *sfAPtr points to the top full scale value and *sfBPtr points to the bottom full scale value.

See **Wave Scaling and Units** on page 129 for a discussion of the distinction between dimension scaling and data full scale.

The function result is 0 or an Igor error code.

Example

```
double sfA;
double sfB;
int result;

if (result = MDGetWaveScaling(waveH, ROWS, &sfA, &sfB))      // Get X scaling
   return result;
if (result = MDGetWaveScaling(waveH, COLUMNS, &sfA, &sfB))   // Get Y scaling
   return result;
```

Thread Safety

MDGetWaveScaling is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

MDSetWaveScaling

```
int
MDSetWaveScaling(waveH, dimension, sfAPtr, sfBPtr)
waveHndl waveH;            // Handle to the wave of interest
int dimension;
double* sfAPtr;            // Points to new delta value
double* sfBPtr;            // Points to new offset value
```

Sets the dimension scaling values or the data full scale values for the wave via sfAPtr and sfBPtr. If dimension is -1, it sets the data full scale values. Otherwise, it sets the dimension scaling for the specified dimension.

For dimension i (i=0 to 3), the scaled index of element e is:

```
   <scaled index> = sfA[i]*e + sfB[i]
```

If dimension is -1, this sets the wave's data full scale setting instead of dimension scaling. *sfAPtr points to the top full scale value and *sfBPtr points to the bottom full scale value.

See **Wave Scaling and Units** on page 129 for a discussion of the distinction between dimension scaling and data full scale.

The function result is 0 or an Igor error code.

Example

This example sets the scaling of the row and column dimensions to the default (scaled value == row/column number) without affecting the scaling of any other dimensions that might exist in the wave.

```
double sfA;
double sfB;
int result;

sfA = 1.0; sfB = 0.0;
if (result= MDSetWaveScaling(waveH, ROWS, &sfA, &sfB))    // Set X scaling
   return result;
sfA = 1.0; sfB = 0.0;
if (result= MDSetWaveScaling(waveH, COLUMNS, &sfA, &sfB))// Set Y scaling
   return result;
```

Thread Safety

MDSetWaveScaling is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

MDGetWaveUnits

```
int
MDGetWaveUnits(waveH, dimension, units)
waveHndl waveH;                  // Handle to the wave of interest
int dimension;
char units[MAX_UNIT_CHARS+1];    // C string
```

Returns the units string for a dimension in the wave or for the wave's data via units. If dimension is -1, it gets the data units. Otherwise, it gets the dimension units for the specified dimension (ROWS, COLUMNS, LAYERS, CHUNKS).

The function result is 0 or an Igor error code.

Units may be up to 49 (MAX_UNIT_CHARS) characters. You should allocate MAX_UNIT_CHARS+1 bytes for units.

See **Wave Scaling and Units** on page 129 for a discussion of the distinction between dimension units and data units.

Example

```
int numDimensions;
int dimension;
char units[MAX_UNIT_CHARS+1];
char buf[256];
int result;

if (result = MDGetWaveDimensions(waveH, &numDimensions, NULL))
   return result;
for (dimension=0; dimension<numDimensions; dimension++) {
   if (result = MDGetWaveUnits(waveH, dimension, units))
      return result;
   sprintf(buf, "Units for dimension %d: \"%s\"" CR_STR, dimension, units);
   XOPNotice(buf);
}
```

Thread Safety

MDGetWaveUnits is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

MDSetWaveUnits

```
int
MDSetWaveUnits(waveH, dimension, units)
waveHndl waveH;                  // Handle to the wave of interest
int dimension;
char units[MAX_UNIT_CHARS+1];    // C string
```

Sets the units string for a dimension in the wave or for the wave's data via units. If dimension is -1, it sets the data units. Otherwise, it sets the dimension units for the specified dimension (ROWS, COLUMNS, LAYERS, CHUNKS).

The function result is 0 or an Igor error code.

Units may be up to 49 (MAX_UNIT_CHARS) characters. If the string you pass is too long, Igor will store a truncated version of it.

See **Wave Scaling and Units** on page 129 for a discussion of the distinction between dimension units and data units.

Example

```
char units[MAX_UNIT_CHARS+1];
int result;

if (result = MDSetWaveUnits(waveH, 0, "s"))  // Set X units to seconds
   return result;
if (result = MDSetWaveUnits(waveH, -1, "v")) // Set data units to volts
   return result;
```

Thread Safety

MDSetWaveUnits is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

MDGetDimensionLabel

```
int
MDGetDimensionLabel(waveH, dimension, element, dimLabel)
waveHndl waveH;            // Handle to the wave of interest
int dimension;             // The dimension of interest.
IndexInt element;          // The element whose label is to be gotten.
char* dimLabel;            // Label returned here.
```

Returns the label for the specified element of the specified dimension as a C string via dimLabel.

You must allocate dimLabel as follows:

```
char dimLabel[MAX_DIM_LABEL_BYTES+1];
```

If element is -1, this specifies a label for the entire dimension. If element is between 0 and n-1, where n is the size of the dimension, then element specifies a label for that element of the dimension only. You will receive an error if dimension or element is less than -1 or greater than n-1.

A dimension label may be empty ("").

The function result is 0 or an Igor error code.

See the WaveAccess sample XOP for an example.

Thread Safety

MDGetDimensionLabel is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

MDSetDimensionLabel

```
int
MDSetDimensionLabel(waveH, dimension, element, dimLabel)
waveHndl waveH;            // Handle to the wave of interest
int dimension;             // The dimension of interest
IndexInt element;          // The element whose label is to be gotten.
const char* dimLabel;      // You pass value here
```

Sets the label for the specified element of the specified dimension.

If element is -1, this specifies a label for the entire dimension. If element is between 0 and n-1, where n is the size of the dimension, then element specifies a label for that element of the dimension only. You will receive an error if dimension or element is less than -1 or greater than n-1.

The function result is 0 or an Igor error code.

See the WaveAccess sample XOP for an example.

Thread Safety

MDSetDimensionLabel is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

GetWaveDimensionLabels

```
int
GetWaveDimensionLabels(waveH, dimLabelsHArray)
waveHndl waveH;                           // Handle to the wave of interest
Handle dimLabelsHArray[MAX_DIMENSIONS];   // Labels returned via this array
```

dimLabelsHArray points to an array of MAX_DIMENSIONS handles. GetWaveDimensionLabels sets each element of this array to a handle containing dimension labels or to NULL.

On output, if the function result is 0 (no error), dimLabelsHArray[i] will be a handle containing dimension labels for dimension i or NULL if dimension i has no dimension labels.

If the function result is non-zero then all handles in dimLabelsHArray will be NULL.

Any non-NULL output handles belong to you. Dispose of them with **WMDisposeHandle** when you are finished with them.

For each dimension, the corresponding dimension label handle consists of an array of N+1 C strings, each in a field of (MAX_DIM_LABEL_BYTES+1) bytes.

The first label is the overall dimension label for that dimension.

Label i+1 is the dimension label for element i of the dimension.

N is the smallest number such that the last non-empty dimension label for a given dimension and all dimension labels before it, whether empty or not, can be stored in the handle.

For example, if a 5 point 1D wave has dimension labels for rows 0 and 2 with all other dimension labels being empty then dimLabelsHArray[0] will contain four dimension labels, one for the overall dimension and three for rows 0 through 2. dimLabelsHArray[0] will not contain any storage for any point after row 2 because the remaining dimension labels for that dimension are empty.

Returns 0 or an error code.

For an example using this routine, see TestGetAndSetWaveDimensionLabels in XOPWaveAccess.c.

Thread Safety

GetWaveDimensionLabels is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

SetWaveDimensionLabels

```
int
SetWaveDimensionLabels(waveH, dimLabelsHArray)
waveHndl waveH;                           // Handle to the wave of interest
Handle dimLabelsHArray[MAX_DIMENSIONS];   // Labels passed in this array
```

dimLabelsHArray points to an array of MAX_DIMENSIONS handles. SetWaveDimensionLabels sets the dimension labels for each existing dimension of waveH based on the corresponding handle in dimLabelsHArray.

The handles in dimLabelsHArray belong to you. Dispose of them with **WMDisposeHandle** when you are finished with them.

See the documentation for **GetWaveDimensionLabels** for a discussion of how the dimension labels are stored in the handles.

Returns 0 or an error code.

For an example using this routine, see TestGetAndSetWaveDimensionLabels in XOPWaveAccess.c.

Thread Safety

SetWaveDimensionLabels is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

MDAccessNumericWaveData

```
int
MDAccessNumericWaveData(waveH, accessMode, dataOffsetPtr)
waveHndl waveH;            // Handle to the wave of interest
int accessMode;
BCInt* dataOffsetPtr;
```

MDAccessNumericWaveData provides one of several methods of access to the data for numeric waves. MDAccessNumericWaveData is the fastest of the access methods but also is the most difficult to use. See **Accessing Numeric Wave Data** on page 124 for a comparison of the various methods.

waveH is the wave handle containing the data you want to access.

accessMode is a code that tells Igor how you plan to access the wave data and is used for a future compatibility check. At present, there is only one accessMode. You should use the symbol kMDWaveAccessMode0 for the accessMode parameter.

On output, if there is no error, *dataOffsetPtr contains the offset in bytes from the start of the wave handle to the data. You can use this offset to point to the start of the wave data in the wave handle. See **Accessing Numeric Wave Data** on page 124 for a discussion of how wave data is layed out in memory.

The function result is 0 or an error code.

If it returns a non-zero error code, you should not attempt to access the wave data but merely return the error code to Igor as the result of your function or operation. At present, there is only one case in which MDAccessNumericWaveData will return an error code – if the wave is a text wave.

Numeric wave data is stored contiguously in the wave handle in one of the supported data types (NT_I8, NT_I16, NT_I32, NT_I64, NT_FP32, NT_FP64). These types will be ORed with NT_CMPLX if the wave is complex and ORed with NT_UNSIGNED if the wave is unsigned integer. 64-bit integer waves (NT_I64) were added in Igor Pro 7.00.

It is possible, though unlikely, that a future version of Igor Pro will store wave data in a different way, such that the current method of accessing wave data will no longer work. If your XOP ever runs with such a future Igor, MDAccessNumericWaveData will return an error code indicating the incompatibility. Your XOP will refrain from attempting to access the wave data and return the error code to Igor. This will prevent a crash and indicate the nature of the problem to the user.

Although they are not truly numeric waves, MDAccessNumericWaveData also allows you to access wave reference waves (WAVE_TYPE) and data folder reference waves (DATAFOLDER_TYPE) which store waveHndls and DataFolderHandles respectively.

To access the a particular point, you need to know the number of data points in each dimension. To find this, you must call MDGetWaveDimensions. This returns the number of used dimensions in the wave and an array of dimension lengths. The dimension lengths are interpreted as follows:

dimSizes[0]	Number of rows in a column
dimSizes[1]	Number of columns in a layer
dimSizes[2]	Number of layers in a chunk
dimSizes[3]	Number of chunks in the wave

The data is stored in row/column/layer/chunk order. This means that, as you step linearly through memory one point at a time, you first pass the value for each row in the first column. At the end of the first column, you reach the start of the second column. After you have passed the data for each column in the first layer, you reach the data for the first column in the second layer. After you have passed the data for each layer, you reach the data for the first layer of the second chunk. And so on.

Example

This example adds one to each element of a wave of two dimensions. It illustrates the difficulty in using MDAccessNumericWaveData - you need to take into account the data type of the wave that you are accessing. The other access methods, described in Chapter 7, don't require this.

```
int numDimensions;
CountInt dimensionSizes[MAX_DIMENSIONS+1];
CountInt numRows, numColumns;
IndexInt row, column;
BCInt dataOffset;
int type, type2, isComplex;
int result;

type = WaveType(waveH);
type2 = type & ~NT_CMPLX;         // Type without the complex bit set
isComplex = type & NT_CMPLX;
if (type2 == TEXT_WAVE_TYPE)
   return NUMERIC_ACCESS_ON_TEXT_WAVE;
if (result = MDGetWaveDimensions(waveH, &numDimensions, dimensionSizes))
   return result;
if (numDimensions != 2)
   return REQUIRES_2D_WAVE;       // An error code defined by your XOP
numRows = dimensionSizes[ROWS];
numColumns = dimensionSizes[COLUMNS];
if (result=MDAccessNumericWaveData(waveH,kMDWaveAccessMode0,&dataOffset))
   return result;

double* dp = (double*)((char*)(*waveH) + dataOffset);
float* fp =(float*)dp;
SInt64* SInt64p = (SInt64*)dp;
SInt32* SInt32p = (SInt32*)dp;
short* sp =(short*)dp;
char* cp =( char*)dp;
UInt64* UInt64p = (UInt64*)dp;
UInt32* UInt32p = (UInt32*)dp;
unsigned short* usp =( unsigned short*)dp;
unsigned char* ucp = (unsigned char*)dp;

for(column=0; column<numColumns; column++) {
   for(row=0; row<numRows; row++) {
      switch(type2) {
         case NT_FP64:
            *dp++ += 1; if (isComplex) *dp++ += 1; break;
         case NT_FP32:
            *fp++ += 1; if (isComplex) *fp++ += 1; break;
         case NT_I64:
            *SInt64p++ += 1; if (isComplex) *SInt64p++ += 1; break;
         case NT_I32:
            *SInt32p++ += 1; if (isComplex) *SInt32p++ += 1; break;
         case NT_I16:
            *sp++ += 1; if (isComplex) *sp++ += 1; break;
         case NT_I8:
            *cp++ += 1; if (isComplex) *cp++ += 1; break;
         case NT_I64 | NT_UNSIGNED:
            *UInt64p++ += 1; if (isComplex) *UInt64p++ += 1; break;
         case NT_I32 | NT_UNSIGNED:
            *UInt32p++ += 1; if (isComplex) *UInt32p++ += 1; break;
         case NT_I16 | NT_UNSIGNED:
            *usp++ += 1; if (isComplex) *usp++ += 1; break;
         case NT_I8 | NT_UNSIGNED:
            *ucp++ += 1; if (isComplex) *ucp++ += 1; break;
         default:       // Unknown data type - possible in a future Igor.
            return NT_FNOT_AVAIL;   // Func not supported on this type.
      }
   }
}
```

Thread Safety

MDAccessNumericWaveData is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

MDGetNumericWavePointValue

```
int
MDGetNumericWavePointValue(waveH, indices, value)
waveHndl waveH;                      // Handle to the wave of interest
IndexInt indices[MAX_DIMENSIONS];    // Identifies the point of interest
double value[2];                     // Value returned here
```

Returns via value the value of a particular element in the specified numeric wave. The value returned is always double precision floating point, regardless of the precision of the wave.

Values returned for signed and unsigned 64-bit integer waves will be imprecise if the value exceeds 2^53 in magnitude because double-precision floating point can not precisely represent integers larger than 2^53. See **64-bit Integer Issues** on page 204 for further discussion. If you must use 64-bit integer waves at full precision, use **MDGetNumericWavePointValueSInt64** or **MDGetNumericWavePointValueUInt64** instead.

indices is an array of dimension indices. For example, for a 3D wave:

indices[0] contains the row number

indices[1] contains the column number

indices[2] contains the layer number

This routine ignores indices for dimensions that do not exist in the wave.

The real part of the value of specified point is returned in value[0]. If the wave is complex, the imaginary part of the value of specified point is returned in value[1]. If the wave is not complex, value[1] is undefined.

The function result is 0 or an error code.

Currently the only error code returned is MD_WAVE_BAD_INDEX, indicating that you have passed one or more invalid indices. An index for a particular dimension is invalid if it is less than zero or greater than or equal to the number of points in the dimension. Future versions of Igor may return other error codes. If you receive an error, just return it to Igor so that it will be reported to the user.

See the example for **MDSetNumericWavePointValue**.

Thread Safety

MDGetNumericWavePointValue is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

MDSetNumericWavePointValue

```
int
MDSetNumericWavePointValue(waveH, indices, value)
waveHndl waveH;                      // Handle to the wave of interest
IndexInt indices[MAX_DIMENSIONS];    // Identifies the point of interest
double value[2];                     // Value passed here
```

Sets the value of a particular point in the specified numeric wave. The value that you supply is always double precision floating point, regardless of the precision of the wave.

Values stored in signed and unsigned 64-bit integer waves will be imprecise if the value exceeds 2^53 in magnitude because double-precision floating point can not precisely represent integers larger than 2^53. See **64-bit Integer Issues** on page 204 for further discussion. If you must use 64-bit integer waves at full precision, use **MDSetNumericWavePointValueSInt64** or **MDSetNumericWavePointValueUInt64** instead.

indices is an array of dimension indices. For example, for a 3D wave:

indices[0] contains the row number

indices[1] contains the column number

indices[2] contains the layer number

This routine ignores indices for dimensions that do not exist in the wave.

You pass in value[0] the real part of the value. If the wave is complex, you pass the imaginary part in value[1]. If the wave is not complex, MDSetNumericWavePointValue ignores value[1].

When storing into an integer wave, MDSetNumericWavePointValue truncates the value that you are storing. If you want, you can do rounding before calling MDSetNumericWavePointValue.

The function result is 0 or an error code.

Currently the only error code returned is MD_WAVE_BAD_INDEX, indicating that you have passed one or more invalid indices. An index for a particular dimension is invalid if it is less than zero or greater than or equal to the number of points in the dimension. Future versions of Igor may return other error codes. If you receive an error, just return it to Igor so that it will be reported to the user.

Example

This example adds one to each element of a wave of two dimensions. It illustrates the ease in using **MDGetNumericWavePointValue** and MDSetNumericWavePointValue – you don't need to user pointers and you don't need to take into account the data type of the wave that you are accessing. However, it is somewhat slower than the other methods. See Chapter 7 for speed comparisons.

```
int numDimensions;
CountInt dimensionSizes[MAX_DIMENSIONS+1];
CountInt numRows, numColumns;
IndexInt row, column;
IndexInt indices[MAX_DIMENSIONS];
int isComplex;
double value[2];
int result;

isComplex = WaveType(waveH) & NT_CMPLX;

if (result = MDGetWaveDimensions(waveH, &numDimensions, dimensionSizes))
   return result;
if (numDimensions != 2)
   return REQUIRES_2D_WAVE;         // An error code defined by your XOP
numRows = dimensionSizes[0];
numColumns = dimensionSizes[1];

MemClear(indices, sizeof(indices)); // Must be 0 for unused dimensions.
```

```
for(column=0; column<numColumns; column++) {
   indices[1] = column;
   for(row=0; row<numRows; row++) {
      indices[0] = row;
      if (result = MDGetNumericWavePointValue(waveH, indices, value))
         return result;
      value[0] += 1;              // Real part
      if (isComplex)
         value[1] += 1;           // Imag part
      if (result = MDSetNumericWavePointValue(waveH, indices, value))
         return result;
   }
}
```

Thread Safety

MDSetNumericWavePointValue is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

MDGetNumericWavePointValueSInt64

```
int
MDGetNumericWavePointValueSInt64(waveH, indices, value)
waveHndl waveH;                   // Handle to the wave of interest
IndexInt indices[MAX_DIMENSIONS]; // Identifies the point of interest
SInt64 value[2];                  // Value returned here
```

Returns via value the value of a particular element in the specified numeric wave. The value returned is always signed 64-bit integer, regardless of the data type of the wave.

This routine can be called for any numeric wave but is intended for use with signed 64-bit integer (NT_I64) waves. For most applications, use **MDGetNumericWavePointValue** instead.

Values returned for floating point waves are truncated to integers. Values returned will be incorrect if the wave value is outside the range of signed 64-bit integers (-9223372036854775808 to 9223372036854775807). These issues do not apply if the data type of the specified wave is NT_I64. See **64-bit Integer Issues** on page 204for further discussion.

indices is an array of dimension indices. For example, for a 3D wave:

indices[0] contains the row number

indices[1] contains the column number

indices[2] contains the layer number

This routine ignores indices for dimensions that do not exist in the wave.

The real part of the value of specified point is returned in value[0]. If the wave is complex, the imaginary part of the value of specified point is returned in value[1]. If the wave is not complex, value[1] is undefined.

The function result is 0 or an error code.

Thread Safety

MDGetNumericWavePointValueSInt64 is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

MDSetNumericWavePointValueSInt64

```
int
MDSetNumericWavePointValueSInt64(waveH, indices, value)
waveHndl waveH;                    // Handle to the wave of interest
IndexInt indices[MAX_DIMENSIONS];  // Identifies the point of interest
SInt64 value[2];                   // Value passed here
```

Sets the value of a particular point in the specified numeric wave. The value that you supply is always signed 64-bit integer, regardless of the data type of the wave.

This routine can be called for any numeric wave but is intended for use with signed 64-bit integer (NT_I64) waves. For most applications, use **MDSetNumericWavePointValue** instead.

Values stored in floating point waves will be imprecise if the value exceeds the range of integers that can be represented precisely in the wave's data type. Values stored in integer waves will be incorrect if value is outside the range that can be represented by the wave's data type. These issues do not apply if the data type of the specified wave is NT_I64. See **64-bit Integer Issues** on page 204 for further discussion.

indices is an array of dimension indices. For example, for a 3D wave:

indices[0] contains the row number

indices[1] contains the column number

indices[2] contains the layer number

This routine ignores indices for dimensions that do not exist in the wave.

You pass in value[0] the real part of the value. If the wave is complex, you pass the imaginary part in value[1]. If the wave is not complex, MDSetNumericWavePointValueSInt64 ignores value[1].

The function result is 0 or an error code.

Thread Safety

MDSetNumericWavePointValueSInt64 is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

MDGetNumericWavePointValueUInt64

```
int
MDGetNumericWavePointValueUInt64(waveH, indices, value)
waveHndl waveH;                    // Handle to the wave of interest
IndexInt indices[MAX_DIMENSIONS];  // Identifies the point of interest
UInt64 value[2];                   // Value returned here
```

Returns via value the value of a particular element in the specified numeric wave. The value returned is always unsigned 64-bit integer, regardless of the data type of the wave.

This routine can be called for any numeric wave but is intended for use with unsigned 64-bit integer (NT_I64 | NT_UNSIGNED) waves. For most applications, use **MDGetNumericWavePointValue** instead.

Values returned for floating point waves are truncated to integers. Values returned will be incorrect if the wave value is outside the range of unsigned 64-bit integers (0 to 18446744073709551615). These issues do not apply if the data type of the specified wave is NT_I64 | NT_UNSIGNED. See **64-bit Integer Issues** on page 204for further discussion.

indices is an array of dimension indices. For example, for a 3D wave:

indices[0] contains the row number

indices[1] contains the column number

indices[2] contains the layer number

This routine ignores indices for dimensions that do not exist in the wave.

The real part of the value of specified point is returned in value[0]. If the wave is complex, the imaginary part of the value of specified point is returned in value[1]. If the wave is not complex, value[1] is undefined.

The function result is 0 or an error code.

Thread Safety

MDGetNumericWavePointValueUInt64 is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

MDSetNumericWavePointValueUInt64

```
int
MDSetNumericWavePointValueUInt64(waveH, indices, value)
waveHndl waveH;                    // Handle to the wave of interest
IndexInt indices[MAX_DIMENSIONS];  // Identifies the point of interest
UInt64 value[2];                   // Value passed here
```

Sets the value of a particular point in the specified numeric wave. The value that you supply is always unsigned 64-bit integer, regardless of the data type of the wave.

This routine can be called for any numeric wave but is intended for use with unsigned 64-bit integer (NT_I64 | NT_UNSIGNED) waves. For most applications, use **MDSetNumericWavePointValue** instead.

Values stored in floating point waves will be imprecise if the value exceeds the range of integers that can be represented precisely in the wave's data type. Values stored in integer waves will be incorrect if value is outside the range that can be represented by the wave's data type. These issues do not apply if the data type of the specified wave is NT_I64 | NT_UNSIGNED. See **64-bit Integer Issues** on page 204 for further discussion.

indices is an array of dimension indices. For example, for a 3D wave:

indices[0] contains the row number

indices[1] contains the column number

indices[2] contains the layer number

This routine ignores indices for dimensions that do not exist in the wave.

You pass in value[0] the real part of the value. If the wave is complex, you pass the imaginary part in value[1]. If the wave is not complex, MDSetNumericWavePointValueUInt64 ignores value[1].

The function result is 0 or an error code.

Thread Safety

MDSetNumericWavePointValueUInt64 is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

MDGetDPDataFromNumericWave

```
int
MDGetDPDataFromNumericWave(waveH, dPtr)
waveHndl waveH;           // Handle to the wave of interest
double* dPtr;             // Where to put the data
```

MDGetDPDataFromNumericWave stores a double-precision copy of the specified numeric wave’s data in the memory pointed to by dPtr. dPtr must point to a block of memory that you have allocated and which must be at least (WavePoints(waveH)*sizeof(double)) bytes or twice that for a complex wave.

Values returned for signed and unsigned 64-bit integer waves will be imprecise if the value exceeds 2^53 in magnitude because double-precision floating point can not precisely represent integers larger than 2^53. If you must use 64-bit integer waves and require full precision for very large values, you must use **MDGetNumericWavePointValueSInt64**, **MDGetNumericWavePointValueUInt64**, or the direct access method as described under **The Direct Access Method** on page 126. See **64-bit Integer Issues** on page 204 for further discussion.

This routine is a companion to MDStoreDPDataInNumericWave.

The function result is zero or an error code.

See the example for **MDStoreDPDataInNumericWave**.

Thread Safety

MDGetDPDataFromNumericWave is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

MDStoreDPDataInNumericWave

```
int
MDStoreDPDataInNumericWave(waveH, dPtr)
waveHndl waveH;            // Handle to the wave of interest
double* dPtr;              // Pointer to the data to store
```

MDStoreDPDataInNumericWave stores the data pointed to by dPtr in the specified numeric wave. During the transfer, it converts the data from double precision to the numeric type of the wave. The conversion is done on-the-fly and the data pointed to by dPtr is not changed.

When storing into an integer wave, MDStoreDPDataInNumericWave truncates the value that you are storing. If you want, you can do rounding before calling MDStoreDPDataInNumericWave.

Values stored for signed and unsigned 64-bit integer waves will be imprecise if the value exceeds 2^53 in magnitude because double-precision floating point can not precisely represent integers larger than 2^53. If you must use 64-bit integer waves and require full precision for very large values, you must use **MDSetNumericWavePointValueSInt64**, **MDSetNumericWavePointValueUInt64**, or the direct access method as described under **The Direct Access Method** on page 126. See **64-bit Integer Issues** on page 204 for further discussion.

This routine is a companion to **MDGetNumericWavePointValue**.

The function result is zero or an error code.

Numeric wave data is stored contiguously in the wave handle in one of the supported data types (see the MakeWave routine). To access the a particular point, you need to know the number of data points in each dimension. To find this, you must call **MDGetWaveDimensions**. This returns the number of used dimensions in the wave and an array of dimension lengths. The dimension lengths are interpreted as follows:

dimensionSizes[ROWS]	Number of rows in a column
dimensionSizes[COLUMNS]	Number of columns in a layer
dimensionSizes[LAYERS]	Number of layers in a chunk
dimensionSizes[CHUNKS]	Number of chunks in the wave

ROWS, COLUMNS, LAYERS and CHUNKS are defined in IgorXOP.h as 0, 1, 2 and 3.

The data is stored in row/column/layer/chunk order. This means that, as you step linearly through memory one point at a time, you first pass the value for each row in the first column. At the end of the first column, you reach the start of the second column. After you have passed the data for each column in the first layer, you reach the data for the first column in the second layer. After you have passed the data for each layer, you reach the data for the first layer of the second chunk. And so on.

Example

This example adds one to each element of a wave of two dimensions. It illustrates the ease in using MDGetDPDataFromNumericWave and MDStoreDPDataInNumericWave – you don't need to take into account the data type of the wave that you are accessing. However, it requires that you make a copy of the wave data which requires more memory than the other methods.

```
int numDimensions;
CountInt dimensionSizes[MAX_DIMENSIONS+1];
CountInt numRows, numColumns;
BCInt numBytes;
IndexInt row, column;
int isComplex;
double* dPtr;
double* dp;
int result;

isComplex = WaveType(waveH) & NT_CMPLX;

if (result = MDGetWaveDimensions(waveH, &numDimensions, dimensionSizes))
   return result;
if (numDimensions != 2)
   return REQUIRES_2D_WAVE;      // An error code defined by your XOP
numRows = dimensionSizes[0];
numColumns = dimensionSizes[1];

numBytes = WavePoints(waveH) * sizeof(double);  // Bytes needed for copy
if (isComplex)
   numBytes *= 2;
dPtr = (double*)WMNewPtr(numBytes);
if (dPtr==NULL)
   return NOMEM;

if (result = MDGetDPDataFromNumericWave(waveH, dPtr)) {
   WMDisposePtr((Ptr)dPtr);
   return result;
}

dp = dPtr;
for(column=0; column<numColumns; column++) {
   for(row=0; row<numRows; row++) {
      *dp++ += 1;       // real part
      if (isComplex)
         *dp++ += 1;    // imag part
   }
}

if (result = MDStoreDPDataInNumericWave(waveH, dPtr)) {
   WMDisposePtr((Ptr)dPtr);
   return result;
}

WMDisposePtr((Ptr)dPtr);
```

Thread Safety

MDStoreDPDataInNumericWave is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

FetchNumericValue

```
int
FetchNumericValue(type, dataStartPtr, index, value)
int type;                  // Igor numeric data type
char* dataStartPtr;        // Pointer to start of wave data
IndexInt index;            // Point number index
double value[2];           // Point value is returned here
```

Returns the value of one element of data of the specified type. The returned value is always double precision floating point.

type is an Igor numeric type (see the **MakeWave** routine).

dataStartPtr points to the start of the numeric data.

index is an index in point numbers from dataStartPtr to the point of interest.

The real part of the value of specified point is returned in value[0].

If the data is complex, the imaginary part of the value of specified point is returned in value[1]. If the data is not complex, value[1] is undefined.

FetchNumericValue is a low-level routine used by **MDGetNumericWavePointValue**. It treats the wave as a linear array, ignoring its dimensionality. Normally, you will have no need to use it directly. However, advanced users may find it useful. It has the ability to convert from any Igor numeric data type to double precision.

Scaling of signed and unsigned 64-bit integer values is subject to inaccuracies for values exceeding 2^53 in magnitude because calculations are done in double-precision and double-precision can not precisely represent the full range of 64-integer values. Values returned for signed and unsigned 64-bit integer data will be imprecise if the value exceeds 2^53 in magnitude because double-precision floating point can not precisely represent integers larger than 2^53. See **64-bit Integer Issues** on page 204 for further discussion.

The function result is zero or an error code.

Thread Safety

FetchNumericValue is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

StoreNumericValue

```
int
StoreNumericValue(type, dataStartPtr, index, value)
int type;                  // Igor numeric data type
char* dataStartPtr;        // Pointer to start of wave data
IndexInt index;            // Point number index
double value[2];           // Point value to be stored
```

Stores the specified value using the specified numeric type.

type is an Igor numeric type (see the **MakeWave** routine).

dataStartPtr points to the start of the numeric data.

index is an index in point numbers from dataStartPtr to the point of interest.

You should pass in value[0] the real part of the value.

If the data is complex, you should pass the complex part in value[1]. If the data is not complex, StoreNumericValue ignores value[1].

Values stored for signed and unsigned 64-bit integer data will be imprecise if the value exceeds 2^53 in magnitude because double-precision floating point can not precisely represent integers larger than 2^53. See **64-bit Integer Issues** on page 204 for further discussion.

StoreNumericValue is a low-level routine used by **MDSetNumericWavePointValue**. It treats the wave as a linear array, ignoring its dimensionality. Normally, you will have no need to use it directly. However, advanced users may find it useful. It has the ability to convert from any Igor numeric data type to double precision.

The function result is zero or an error code.

Thread Safety

StoreNumericValue is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

MDGetTextWavePointValue

```
int
MDGetTextWavePointValue(waveH, indices, textH)
waveHndl waveH;                    // Handle to the wave of interest
IndexInt indices[MAX_DIMENSIONS];  // Identifies the point of interest
Handle textH;                      // Value returned here
```

Returns via textH the value of a particular element in the specified wave.

The value is returned in the textH handle, which you must allocate before calling MDGetTextWavePoint-Value. Any previous contents of textH are overwritten. textH is yours to dispose when you are finished with it.

If the wave is not a text wave, returns an error code and does not alter textH.

indices is an array of dimension indices. For example, for a 3D wave:

indices[0] should contain the row number

indices[1] should contain the column number

indices[2] should contain the layer number

This routine ignores indices for dimensions that do not exist in the wave.

The function result is 0 or an error code.

On output, if there is no error, textH contains a copy of the characters in the specified wave element. An element in an Igor text wave can contain any number of characters, including zero. Therefore, the handle can contain any number of characters. Igor text waves can contain any characters, including control characters. No characters codes are considered illegal.

Note that the text in the handle is *not* null terminated. Use **WMGetHandleSize** to find the number of bytes in the handle. To use C string functions on this text you need to copy it to a local buffer and null-terminate it or add a null terminator to the handle. If you pass the handle back to Igor, you must remove the null terminator. See **Understand the Difference Between a String in a Handle and a C String** on page 221.

See the example below for MDSetTextWavePointValue.

Thread Safety

MDGetTextWavePointValue is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

MDSetTextWavePointValue

```
int
MDSetTextWavePointValue(waveH, indices, textH)
waveHndl waveH;                      // Handle to the wave of interest
IndexInt indices[MAX_DIMENSIONS];    // Identifies the point of interest
Handle textH;                        // Value to store in wave
```

Transfers the characters in textH to the specified point in the specified wave. The contents of textH is not altered.

If the wave is not a text wave, returns an error code.

indices is an array of dimension indices. For example, for a 3D wave:

indices[0] should contain the row number

indices[1] should contain the column number

indices[2] should contain the layer number

This routine ignores indices for dimensions that do not exist in the wave.

A point in an Igor text wave can contain any number of characters, including zero. Therefore, the handle can contain any number of characters. Igor text waves can contain any characters, including control characters. No characters codes are considered illegal.

The text in the handle must not be null terminated. If you have added a null terminator to the handle, remove it before calling MDSetTextWavePointValue.

After calling MDSetTextWavePointValue, the handle is still yours so you should dispose it when you no longer need it.

The function result is 0 or an error code.

Example

This example adds an asterisk to each element of a wave of two dimensions. It illustrates the ease of using **MDGetTextWavePointValue** and MDSetTextWavePointValue. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

```
int numDimensions;
IndexInt dimensionSizes[MAX_DIMENSIONS+1];
CountInt numRows, numColumns;
IndexInt row, column;
IndexInt indices[MAX_DIMENSIONS];
Handle textH;
int result;

if (result = MDGetWaveDimensions(waveH, &numDimensions, dimensionSizes))
   return result;
if (numDimensions != 2)
   return REQUIRES_2D_WAVE;      // An error code defined by your XOP
numRows = dimensionSizes[ROWS];
numColumns = dimensionSizes[COLUMNS];
textH = WMNewHandle(0L);
if (textH == NULL)
   return NOMEM;

MemClear(indices, sizeof(indices));
for(column=0; column<numColumns; column++) {
   indices[1] = column;
   for(row=0; row<numRows; row++) {
      indices[0] = row;
      if (result = MDGetTextWavePointValue(waveH, indices, textH))
```

```
         break;
      if (WMPtrAndHand("*", textH, 1)) {  // Append an asterisk to handle
         result = NOMEM;
         break;
      }
      if (result = MDSetTextWavePointValue(waveH, indices, textH))
         break;
   }
}

WMDisposeHandle(textH);
```

Thread Safety

MDSetTextWavePointValue is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

GetTextWaveData

```
int
GetTextWaveData(waveH, mode, textDataHPtr)
waveHndl waveH;            // Handle to the wave of interest
int mode;                  // Determines format of returned data
Handle* textDataHPtr;      // Data is returned here
```

Returns all of the text for the specified text wave via textDataHPtr.

NOTE: This routine is for advanced programmers who are comfortable with pointer arithmetic and handles. Less experienced programmers should use **MDGetTextWavePointValue** to get the wave text values one at a time.

If the function result is 0 then *textDataHPtr is a handle that you own. When you are finished, dispose of it using **WMDisposeHandle**.

In the event of an error, the function result will be non-zero and *textDataHPtr will be NULL.

The returned handle will contain the text for all of the wave's elements in one of several formats explained below. The format depends on the mode parameter.

Modes 0 and 1 use a null byte to mark the end of a string and thus will not work if 0 is considered to be a legal character value.

Mode	Data Format

Mode=0	The returned handle contains one null-terminated C string for each element of the wave.
	Example:
	`"Zero"<null>`
	`"One"<null>`
	`"Two"<null>`

Mode=1	The returned handle contains a list of offsets to strings followed by the string data. There is one extra offset which is the offset to where the string would be for the next element if the wave had one more element.
	The offsets are 32 bits in IGOR32 and 64 bits in IGOR64.
	The text for each element in the wave is represented by a null-terminated C string.
	Example:
	`<Offset to "Zero">`
	`<Offset to "One">`
	`<Offset to "Two">`
	`<Extra offset>`
	`"Zero"<null>`
	`"One"<null>`
	`"Two"<null>`

Mode=2	The returned handle contains a list of offsets to strings followed by the string data.
	The offsets are 32 bits in IGOR32 and 64 bits in IGOR64.
	The text for each element in the wave is not null-terminated.
	Example:
	`<Offset to "Zero">`
	`<Offset to "One">`
	`<Offset to "Two">`
	`<Extra offset>`
	`"Zero"`
	`"One"`
	`"Two"`

Using modes 1 and 2, you can determine the length of element i by subtracting offset i from offset i+1.

You can convert the offsets into pointers to strings by adding **textDataHPtr to each of the offsets.

For the purposes of GetTextWaveData, the wave is treated as a 1D wave regardless of its true dimensionality. If waveH a 2D text wave, the data returned via textDataHPtr is in column-major order. This means that the data for each row of the first column appears first in memory, followed by the data for the each row of the next column, and so on.

As explained under **WM Memory XOPSupport Routines** on page 179, on Macintosh the Handle data types are limited to 2 GB. If the wave text data requires more than 2 GB, GetTextWaveData will fail and return an error, even when running IGOR64.

Returns 0 or an error code.

For an example using this routine, see TestGetAndSetTextWaveData in XOPWaveAccess.c.

Thread Safety

GetTextWaveData is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

SetTextWaveData

```
int
SetTextWaveData(waveH, mode, textDataH)
waveHndl waveH;            // Handle to the wave of interest
int mode;                  // Determines format of returned data
Handle textDataH;          // Data is passed to Igor here
```

Sets all of the text for the specified text wave according to textDataH.

NOTE: This routine is for advanced programmers who are comfortable with pointer arithmetic and handles. Less experienced programmers should use **MDSetTextWavePointValue** to get the wave text values one at a time.

WARNING: If you pass inconsistent data in textDataH you will cause Igor to crash.

SetTextWaveData can not change the number of points in the text wave. Therefore the data in textDataH must be consistent with the number of points in waveH. Otherwise a crash will occur.

Also, when using modes 1 or 2, the offsets must be correct. Otherwise a crash will occur. The offsets are 32 bits in IGOR32 and 64 bits in IGOR64.

Crashes caused by inconsistent data may occur at unpredictable times making it hard to trace it to the problem. So triple-check your code.

You own the textDataH handle. When you are finished with it, dispose of it using **WMDisposeHandle**.

The format of textDataH depends on the mode parameter. See the documentation for **GetTextWaveData** for a description of these formats.

Modes 0 and 1 use a null byte to mark the end of a string and thus will not work if 0 is considered to be a legal character value.

As explained under **WM Memory XOPSupport Routines** on page 179, on Macintosh the Handle data types are limited to 2 GB. If the wave text data requires more than 2 GB, you can not use SetTextWave-Data, even when running IGOR64.

Returns 0 or an error code.

For an example using this routine, see TestGetAndSetTextWaveData in XOPWaveAccess.c.

SetTextWaveData returns an error if the wave is locked or if the wave was passed to a thread as a parame-ter to the thread worker function.

Thread Safety

SetTextWaveData is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

HoldWave

```
int
HoldWave(waveH)
waveHndl waveH;
```

waveH is a wave handle that you have obtained from Igor.

If waveH is NULL, HoldWave does nothing and returns 0.

HoldWave tells Igor that you are holding a handle referencing the wave and that it should not be deleted until you release it by calling **ReleaseWave**. This prevents a crash that would occur if Igor deleted a wave to which you held a handle and you later used that handle.

In most XOP programming, such as a straight-forward external operation or external function, you do not need to call HoldWave/ReleaseWave. If you are just using the wave handle temporarily during the execution of your external function or operation and you make no calls that could potentially delete the wave then you do not need to and should not call HoldWave and ReleaseWave.

You need to call HoldWave/ReleaseWave only if you are storing a wave handle over a period during which Igor could delete the wave. For example, you might indefinitely store a wave handle in a global variable or you might do a callback, such as **XOPCommand** or **CallFunction**, that could cause the wave to be deleted. In such cases, call HoldWave to prevent Igor from deleting the wave until you are finished with it. Then call ReleaseWave to permit Igor to delete the wave.

HoldWave returns 0 or IGOR_OBSOLETE as the function result.

See **Wave Reference Counting** on page 131 for background information and further details.

HoldWave returns an error code as the function result, typically 0 for success or IGOR_OBSOLETE.

Thread Safety

HoldWave is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

ReleaseWave

```
int
ReleaseWave(waveRefPtr)
waveHndl* waveRefPtr;
```

Tells Igor that you are no longer holding a wave.

waveRefPtr contains the address of your waveHndl variable that refers to a wave. ReleaseWave sets *waveRefPtr to NULL so your waveHndl variable is not valid after you call ReleaseWave.

If *waveRefPtr is NULL on input then ReleaseWave does nothing and returns 0.

See **Wave Reference Counting** on page 131 for details.

ReleaseWave returns an error code as the function result, typically 0 for success or IGOR_OBSOLETE.

Thread Safety

ReleaseWave is Igor-thread-safe with certain exceptions explained under **Waves Passed to Igor Threads as Parameters** on page 161. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

Routines for Accessing Variables

These routines allow you to create or get or set the value of Igor numeric and string variables.

Most of the routines listed in this section deal with global variables in the current data folder. The exceptions are **GetNVAR**, **SetNVAR**, **GetSVAR** and **SetSVAR** which are used in conjunction with fields in Igor Pro structures to access global variables referenced by NVAR and SVAR variables in user-defined functions.

In addition to the routines in this section, you can use **GetDataFolderObject** and **SetDataFolderObject** to access global variables.

These routines do not permit you to access local variables in user-defined functions.

The routines in this section can also be used to create, set and read macro-local variables. Since macro programming is deprecated, we recommend that you use these routines to deal with global variables only. Some of the routines have a parameter that allows you to specify that you want to deal with global variables.

Routines that deal with variables used by Operation Handler-based external operations are described under **Operation Handler Routines** on page 230.

To set file loader output variables, see **Routines for File-Loader XOPs** on page 328.

Variable

```
int
Variable(varName, varType)
char* varName;              // C string containing name of variable
int varType;                // Data type of variable
```

NOTE: We recommend that you use **SetIgorIntVar**, **SetIgorFloatingVar**, **SetIgorComplexVar** or **SetIgorStringVar** instead of Variable as they are easier to use.

When called from the command line or from a user-defined function, Variable creates a global numeric or string variable in the current data folder.

When called from a macro, if the VAR_GLOBAL bit is set in the varType parameter, Variable creates a global numeric or string variable in the current data folder. If VAR_GLOBAL is cleared Variable creates a macro-local variable. To give consistent behavior it is recommended that you always set the VAR_GLOBAL bit.

You can not create a local variable in a user-defined function except through **Operation Handler** (see page 72).

When your XOP is called from the command line or from a user-defined function, the varType parameter is defined as follows:

varType	Action
0 or VAR_GLOBAL	Creates global string variable
NT_FP64 or (NT_FP64 | VAR_GLOBAL)	Creates global numeric variable
(NT_FP64 | NT_CMPLX) or (NT_FP64 | NT_CMPLX | VAR_GLOBAL)	Creates global complex numeric variable

If you omit VAR_GLOBAL and you were called from a macro then a macro-local variable is created.

The function result is 0 if Variable was able to create the variable or an Igor error code if not.

Prior to Igor Pro 5, Variable was used to create output variables from external operations, analogous to V_flag or S_fileName. Now you should use **Operation Handler** (see page 72) to implement your external operation. Operation Handler will create output variables for you so you should not use Variable for that purpose.

Prior to Igor Pro 7, Variable allowed you to create a variable with a liberal name. This caused problems later because Igor does not support liberal names for variables. With Igor Pro 7 or later, Variable returns an error if the name is not a valid standard Igor name.

Example

```
static int
Test(void)
{
   // These will always create global variables even if called from a macro.
   Variable("globalNumericVar", NT_FP64 | VAR_GLOBAL);
   Variable("globalStringVar", 0 | VAR_GLOBAL);
}
```

Thread Safety

Variable is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

FetchNumVar

```
int
FetchNumVar(varName, doublePtr1, doublePtr2)
char* varName;              // C string containing name of variable
double* doublePtr1;         // Receives contents of real part of variable
double* doublePtr2;         // Receives contents of imag part of variable
```

Returns the value of the named Igor numeric variable.

When called from the command line or from a user-defined function, FetchNumVar looks for a global variable in the current data folder.

When called from a macro, FetchNumVar first looks for a macro-local variable with the specified name. If none is found, it looks for a global variable in the current data folder.

You can not fetch a local variable in a user-defined function except through **Operation Handler** (see page 72).

Returns -1 if the variable does not exist or the numeric type of the variable if it does.

The returned numeric type will be either NT_FP64 (double-precision) or (NT_FP64 | NT_CMPLX) (double-precision, complex).

If the variable is not complex, the value returned through doublePtr2 is undefined but you still must pass in a pointer to a valid double because some versions of Igor will access it even if the Igor variable is not complex.

Thread Safety

FetchNumVar is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

StoreNumVar

```
int
StoreNumVar(varName, doublePtr1, doublePtr2)
char* varName;              // C string containing name of variable
double* doublePtr1;         // Points to value to store in real part
double* doublePtr2;         // Points to value to store in imag
```

NOTE: We recommend that you use **SetIgorIntVar**, **SetIgorFloatingVar** or **SetIgorComplexVar** instead of StoreNumVar as they are easier to use.

Sets the value of the named Igor variable.

When called from the command line or from a user-defined function, StoreNumVar looks for a global variable in the current data folder.

When called from a macro, StoreNumVar first looks for a macro-local variable with the specified name. If none is found, it looks for a global variable in the current data folder.

You can not set a local variable in a user-defined function except through **Operation Handler** (see page 72).

Returns -1 if the variable does not exist or the numeric type of the variable if it does.

The numeric type will be either NT_FP64 (double-precision) or (NT_FP64 | NT_CMPLX) (double-precision, complex).

If the variable is not complex, the value pointed to by doublePtr2 does not matter but it must point to a valid double variable because some versions of Igor will access it even if the Igor variable is not complex.

Thread Safety

StoreNumVar is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

FetchStrVar

```
int
FetchStrVar(varName, stringPtr)
char* varName;              // C string containing name of string
char stringPtr[256];        // Receives contents of string
```

Fetches the contents of the named Igor string variable.

When called from the command line or from a user-defined function, FetchStrVar looks for a global variable in the current data folder.

When called from a macro, FetchStrVar first looks for a macro-local variable with the specified name. If none is found, it looks for a global variable in the current data folder.

You can not fetch a local variable in a user-defined function except through **Operation Handler** (see page 72).

The function result is 0 if it was able to fetch the string or an Igor error code if the string variable does not exist.

stringPtr must point to an array of 256 characters.

On output, stringPtr contains a null-terminated C string.

FetchStrVar will never return more than 255 characters. If you want to access any characters beyond the first 255, use **FetchStrHandle** instead of FetchStrVar.

Thread Safety

FetchStrVar is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

StoreStrVar

```
int
StoreStrVar(varName, stringPtr)
char* varName;            // C string containing name of string
char* stringPtr;          // C string to store in string variable
```

NOTE: We recommend that you use **SetIgorStringVar** instead of StoreStrVar as it is easier to use.

Sets the contents of the named Igor string variable.

When called from the command line or from a user-defined function, StoreStrVar looks for a global variable in the current data folder.

When called from a macro, StoreStrVar first looks for a macro-local variable with the specified name. If none is found, it looks for a global variable in the current data folder.

You can not set a local variable in a user-defined function except through **Operation Handler** (see page 72).

The function result is 0 if it was able to store the string or an Igor error code if the string variable does not exist.

stringPtr is a null-terminated C string.

There is no limit to the length of the C string pointed to by stringPtr.

Thread Safety

StoreStrVar is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

FetchStrHandle

```
Handle
FetchStrHandle(varName)
char* varName;            // C string containing name of string
```

Returns the handle containing the text for the named Igor string variable.

Returns NULL if there is no such string variable.

When called from the command line or from a user-defined function, FetchStrHandle looks for a global variable in the current data folder.

When called from a macro, FetchStrHandle first looks for a macro-local variable with the specified name. If none is found, it looks for a global variable in the current data folder.

You can not fetch a local variable in a user-defined function except through **Operation Handler** (see page 72).

Note that the text in the handle is *not* null terminated. Use **WMGetHandleSize** to find the number of bytes in the handle. To use C string functions on this text you need to copy it to a local buffer and null-terminate it or add a null terminator to the handle. You must remove the null terminator before control returns to Igor. See **Understand the Difference Between a String in a Handle and a C String** on page 221**.**

NOTE: The returned handle belongs to Igor. You must not dispose of or otherwise modify this handle.

You must use the handle immediately and then not refer to it again since Igor will dispose it if the user kills the string variable.

Thread Safety

FetchStrHandle is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

SetIgorIntVar

```
int
SetIgorIntVar(numVarName, value, forceGlobal)
char* numVarName;          // Name of the Igor numeric variable to set
int value;                 // Value to set it to
int forceGlobal;           // Non-zero to create a global variable
```

Creates an Igor numeric variable if it does not already exist. Sets the variable to an integer value.

When called from the command line or from a user-defined function, SetIgorIntVar always creates and/or sets a global variable in the current data folder.

When called from a macro, SetIgorIntVar creates and/or sets a global variable in the current data folder if forceGlobal is non-zero and creates and/or sets a macro-local variable if forceGlobal is 0. To get consistent behavior regardless of how you are called, pass 1 for forceGlobal.

You can not set a local variable in a user-defined function except through **Operation Handler** (see page 72).

The function result is 0 or an error code.

In the event of a name conflict with a wave or string variable in the same scope, SetIgorIntVar will return an error.

Prior to Igor Pro 5, SetIgorIntVar was used to create output variables from external operations, analogous to V_flag. Now you should use **Operation Handler** (see page 72) to implement your external operation. Operation Handler will create output variables for you so you should not use SetIgorIntVar for that purpose.

Prior to Igor Pro 7, SetIgorIntVar allowed you to create a variable with a liberal name. This caused problems later because Igor does not support liberal names for variables. With Igor Pro 7 or later, SetIgorIntVar returns an error if the name is not a valid standard Igor name.

Thread Safety

SetIgorIntVar is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

SetIgorFloatingVar

```
int
SetIgorFloatingVar(numVarName, valuePtr, forceGlobal)
char* numVarName;          // Name of the Igor numeric variable to set
double* valuePtr;          // Pointer to double value to set it to
int forceGlobal;           // Non-zero to create a global variable
```

Creates an Igor numeric variable if it does not already exist. Sets the variable to a floating-point value.

When called from the command line or from a user-defined function, SetIgorFloatingVar always creates and/or sets a global variable in the current data folder.

When called from a macro, SetIgorFloatingVar creates and/or sets a global variable in the current data folder if forceGlobal is non-zero and creates and/or sets a macro-local variable if forceGlobal is 0. To get consistent behavior regardless of how you are called, pass 1 for forceGlobal.

You can not set a local variable in a user-defined function except through **Operation Handler** (see page 72).

The function result is 0 or an error code.

In the event of a name conflict with a wave or string variable in the same scope, SetIgorFloatingVar will return an error.

Prior to Igor Pro 5, SetIgorFloatingVar was used to create output variables from external operations, analogous to V_flag. Now you should use **Operation Handler** (see page 72) to implement your external operation. Operation Handler will create output variables for you so you should not use SetIgorFloatingVar for that purpose.

Prior to Igor Pro 7, SetIgorFloatingVar allowed you to create a variable with a liberal name. This caused problems later because Igor does not support liberal names for variables. With Igor Pro 7 or later, SetIgor-FloatingVar returns an error if the name is not a valid standard Igor name.

Thread Safety

SetIgorFloatingVar is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

SetIgorComplexVar

```
int
SetIgorComplexVar(numVarName, realPtr, imagPtr, forceGlobal)
char* numVarName;        // Name of the Igor complex numeric variable to set
double* realPtr;         // Pointer to real part of value to set it to
double* imagPtr;         // Pointer to imaginary part of value to set it to
int forceGlobal;         // Non-zero to create a global variable
```

Creates an Igor complex numeric variable if it does not already exist. Sets the variable to a complex floating-point value.

When called from the command line or from a user-defined function, SetIgorComplexVar always creates and/or sets a global variable in the current data folder.

When called from a macro, SetIgorComplexVar creates and/or sets a global variable in the current data folder if forceGlobal is non-zero and creates and/or sets a macro-local variable if forceGlobal is 0. To get consistent behavior regardless of how you are called, pass 1 for forceGlobal.

You can not set a local variable in a user-defined function except through **Operation Handler** (see page 72).

The function result is 0 or an error code.

In the event of a name conflict with a wave or string variable in the same scope, SetIgorComplexVar will return an error.

Prior to Igor Pro 5, SetIgorComplexVar was used to create output variables from external operations, analogous to V_flag. Now you should use **Operation Handler** (see page 72) to implement your external operation. Operation Handler will create output variables for you so you should not use SetIgorComplexVar for that purpose.

Prior to Igor Pro 7, SetIgorComplexVar allowed you to create a variable with a liberal name. This caused problems later because Igor does not support liberal names for variables. With Igor Pro 7 or later, SetIgor-ComplexVar returns an error if the name is not a valid standard Igor name.

Thread Safety

SetIgorComplexVar is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

SetIgorStringVar

```
int
SetIgorStringVar(stringVarName, stringVarValue, forceGlobal)
char* stringVarName;        // Name of the Igor string variable to set
char* stringVarValue;       // C string value to store in string variable
int forceGlobal;            // Non-zero to create a global string
```

Creates an Igor string variable if it does not already exist. Stores the specified string in the variable.

When called from the command line or from a user-defined function, SetIgorStringVar always creates and/or sets a global variable in the current data folder.

When called from a macro, SetIgorStringVar creates and/or sets a global variable in the current data folder if forceGlobal is non-zero and creates and/or sets a macro-local variable if forceGlobal is 0. To get consistent behavior regardless of how you are called, pass 1 for forceGlobal.

You can not set a local variable in a user-defined function except through **Operation Handler** (see page 72).

stringVarValue is a null-terminated C string of any length.

The function result is 0 or an error code.

In the event of a name conflict with a wave or numeric variable in the same scope, SetIgorStringVar will return an error.

Prior to Igor Pro 5, the SetIgorStringVar function was used to create output variables from external operations, analogous to S_fileName. Now you should use **Operation Handler** (see page 72) to implement your external operation. Operation Handler will create output variables for you so you should not use SetIgorStringVar for that purpose.

Thread Safety

SetIgorStringVar is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

GetNVAR

```
int
GetNVAR(nvp, realPartPtr, imagPartPtr, numTypePtr)
NVARRec* nvp;              // Pointer to an NVARRec field in a structure
double* realPartPtr;       // Real part of variable returned here
double* imagPartPtr;       // Imaginary part of variable returned here
int* numTypePtr;           // Numeric type of variable returned here
```

Retrieves the data and type of a global numeric variable referenced by an NVAR field in an Igor Pro structure.

nvp is a pointer to an NVAR field in an Igor structure. The Igor structure pointer would be passed into the XOP as a parameter to an external operation or external function.

If GetNVAR returns 0 then *realPartPtr will be the contents of the real part of the global variable and *imagPartPtr will be the contents of the imaginary part of the global variable, if it is complex.

realPartPtr and imagPartPtr must each point to storage for a double whether the global variable is complex or not.

*numTypePtr is set to the numeric type of the global. This will be either NT_FP64 or (NT_FP64 | NT_CMPLX).

Returns 0 or an error code.

See also **NVARs and SVARs In Structures** on page 196.

Thread Safety

GetNVAR is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

SetNVAR

```
int
SetNVAR(nvp, realPartPtr, imagPartPtr)
NVARRec* nvp;               // Pointer to an NVARRec field in a structure
double* realPartPtr;        // Real part of variable supplied here
double* imagPartPtr;        // Imaginary part of variable supplied here
```

Sets the value of a global numeric variable referenced by an NVAR field in an Igor Pro structure.

nvp is a pointer to an NVAR field in an Igor structure. The Igor structure pointer would be passed into the XOP as a parameter to an external operation or external function.

*realPartPtr is the value to store in the real part of the global variable and *imagPartPtr is the value to store in the imaginary part of the global variable, if it is complex.

realPartPtr and imagPartPtr must each point to storage for a double whether the global variable is complex or not.

Returns 0 or an error code.

See also **NVARs and SVARs In Structures** on page 196.

Thread Safety

SetNVAR is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

GetSVAR

```
int
GetSVAR(nvp, strHPtr)
NVARRec* nvp;               // Pointer to an NVARRec field in a structure
Handle* strHPtr;            // Handle for string variable returned here
```

Retrieves the handle for a global string variable referenced by an SVAR field in an Igor Pro structure.

svp is a pointer to an SVAR field in an Igor structure. The Igor structure pointer would be passed into the XOP as a parameter to an external operation or external function.

If GetSVAR returns 0 then *strHPtr will be the handle for an Igor global string variable.

NOTE: *strHPtr can be NULL if the global string variable contains no characters. You must test for this case before using *strHPtr.

NOTE: *strHPtr belongs to Igor. Do not dispose it or alter it. Use this function only to read the contents of the string.

Note that the text in the handle is *not* null terminated. Use **WMGetHandleSize** to find the number of bytes in the handle. To use C string functions on this text you need to copy it to a local buffer and null-terminate it or add a null terminator to the handle. You must remove the null terminator before control returns to Igor. See **Understand the Difference Between a String in a Handle and a C String** on page 221**.**

Returns 0 or an error code.

See also **NVARs and SVARs In Structures** on page 196.

Thread Safety

GetSVAR is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

SetSVAR

```
int
SetSVAR(nvp, strH)
NVARRec* nvp;               // Pointer to an NVARRec field in a structure
Handle* strH;               // Handle containing text for string variable
```

Sets the value of a global string variable referenced by an SVAR field in an Igor Pro structure.

svp is a pointer to an SVAR field in an Igor structure. The Igor structure pointer would be passed into the XOP as a parameter to an external operation or external function.

strH is a handle that you own. It can be NULL to set the global string variable to empty.

NOTE: Igor copies the contents of strH. You retain ownership of it and must dispose it.

Note that the text in the handle is *not* null terminated. See **Understand the Difference Between a String in a Handle and a C String** on page 221**.**

Returns 0 or an error code.

See also **NVARs and SVARs In Structures** on page 196.

Thread Safety

SetSVAR is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

Routines for Accessing Data Folders

Data folders provide hierarchical data storage for Igor data. Most simple XOPs have no need to deal with them. For some advanced applications, being data-folder-aware will make your XOP more powerful. See **Dealing With Data Folders** on page 141 for an orientation to data folder use in XOPs.

Many of these routines require that you pass a data folder handle to Igor. You obtain a data folder handle from Igor via a DataFolderAndName operation parameter or by calling one of these routines:

GetRootDataFolder	**GetCurrentDataFolder**	**GetNamedDataFolder**
GetDataFolderByIDNumber	**GetParentDataFolder**	**GetIndexedChildDataFolder**
GetDataFolderObject	**GetWavesDataFolder**	**NewDataFolder**

Data folder handles belong to Igor and your XOP must not delete or directly modify them.

GetDataFolderNameOrPath

```
int
GetDataFolderNameOrPath(dataFolderH, flags, dataFolderPathOrName)
DataFolderHandle dataFolderH;
int flags;
char dataFolderPathOrName[MAXCMDLEN+1];
```

Given a handle to a data folder, returns the name of the data folder if bit 0 of flags is zero or a full path to the data folder, including a trailing colon, if bit 0 of flags is set.

If bit 1 of flags is set, Igor returns the dataFolderPathOrName with single quotes if they would be needed to use the name or path in Igor's command line. If bit 1 of flags is zero, dataFolderPathOr-Name will have no quotes.

Set bit 1 of flags if you are going to use the path or name in a command that you submit to Igor via the XOPCommand or XOPSilentCommand callbacks. Clear bit 1 of flags for other purpose if you want an unquoted path or name.

All other bits of the flags parameter are reserved; you must set them to zero.

If dataFolderH is NULL, GetDataFolderNameOrPath uses the current data folder.

A data folder name can be up to MAX_OBJ_NAME characters while a full or partial path can be up to MAXCMDLEN characters. To be safe, allocate MAXCMDLEN+1 characters for dataFolderPathOrName.

The function result is 0 or error code.

Thread Safety

GetDataFolderNameOrPath is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

GetDataFolderIDNumber

```
int
GetDataFolderIDNumber(dataFolderH, IDNumberPtr)
DataFolderHandle dataFolderH;
int* IDNumberPtr;
```

Returns the unique ID number for the data folder via IDNumberPtr.

If dataFolderH is NULL, GetDataFolderIDNumber uses the current data folder.

Data folder ID numbers are supported for data folders that are part of the main data hierarchy only. They are not supported for free root data folders and their descendants or for preemptive thread root data folders and their descendants.

In Igor Pro 8.05 and later, all free root data folders and their descendants and all preemptive thread root data folders and their descendants have ID numbers less than zero. These are not valid ID numbers and can not be used with GetDataFolderByIDNumber to get the data folder handle.

Prior to Igor Pro 8.05, GetDataFolderIDNumber incorrectly returned 0 for free root data folders and their descendants. 0 is the ID number for the root data folder of the main thread. Because of this, when running with Igor Pro 8.04 or before, GetDataFolderIDNumber returns misleading information.

The following discussion refers to data folders in the main thread's data hierarchy only.

Each data folder in the main thread's data hierarchy has a unique ID number that stays the same as long as the data folder exists, even if it is renamed or moved. If you need to reference a data folder over a period of time during which it could be killed, then you should store the data folder's ID number.

Given the ID number, you can call **GetDataFolderByIDNumber** to check if the data folder still exists and to get a handle to it.

The ID number is valid until the user creates a new Igor experiment or quits Igor. ID numbers are not remembered from one running of Igor to the next.

The function result is 0 or error code.

Thread Safety

GetDataFolderIDNumber is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

GetDataFolderProperties

```
int
GetDataFolderProperties(dataFolderH, propertiesPtr)
DataFolderHandle dataFolderH;
int* propertiesPtr;
```

Returns the bit-flag properties of the specified data folder.

If dataFolderH is NULL, it uses the current data folder.

At present, Igor does not support any properties and this routine will always return 0 in *propertiesPtr. In the future, it might support properties such as "locked".

The function result is 0 or error code.

Thread Safety

GetDataFolderProperties is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

SetDataFolderProperties

```
int
SetDataFolderProperties(dataFolderH, properties)
DataFolderHandle dataFolderH;
int properties;
```

Sets the bit-flag properties of the specified data folder.

If dataFolderH is NULL, it uses the current data folder.

At present, Igor does not support any properties and this routine does nothing. In the future, it might support properties such as "locked".

The function result is 0 or error code.

Thread Safety

SetDataFolderProperties is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

GetDataFolderListing

```
int
GetDataFolderListing(dataFolderH, optionsFlag, listingH)
DataFolderHandle dataFolderH;
int optionsFlag;           // Specifies what is to be listed
Handle listingH;           // Listing text is stored in handle.
```

Returns via listingH a listing of the contents of the specified data folder.

You must create listingH and dispose it when you no longer need it. Any contents in listingH are replaced by the listing.

Note that the text in the handle is *not* null terminated. Use **WMGetHandleSize** to find the number of bytes in the handle. To use C string functions on this text you need to copy it to a local buffer and null-terminate it or add a null terminator to the handle and lock the handle. See **Understand the Difference Between a String in a Handle and a C String** on page 221.

If dataFolderH is NULL, GetDataFolderListing uses the current data folder.

optionsFlag determines what is in the listing.

If bit 0 of optionsFlag is set, a list of subfolders is included:

```
   "FOLDERS:<subFolder0>,<subFolder1>...,<subFolderN>;<CR>"
```

If bit 1 of optionsFlag is set, a list of waves is included:

```
   "WAVES:<waveName0>,<waveName1>...,<waveNameN>;<CR>"
```

If bit 2 of optionsFlag is set, a list of numeric variables is included:

```
   "VARIABLES:<varName0>,<varName1>...,<varNameN>;<CR>"
```

If bit 3 of optionsFlag is set, a list of string variables is included:

```
   "STRINGS:<strVarName0>,<strVarName1>...,<strVarNameN>;<CR>"
```

All other bits are reserved and should be set to zero.

Names in the listing of waves, variables and strings are quoted with single quotes if this is necessary to make them suitable for use in the Igor command line.

The function result is 0 or error code.

Example

```
DataFolderHandle dataFolderH;
Handle listingH;
int result;

listingH = WMNewHandle(0L);
if (listingH == NULL)
   return NOMEM;
if (result = GetRootDataFolder(0, &dataFolderH)
   return result;
if (result = GetDataFolderListing(dataFolderH, 15, &listingH))
   return result;
<Use contents of listingH>
WMDisposeHandle(listingH);
```

Thread Safety

GetDataFolderListing is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

GetRootDataFolder

```
int
GetRootDataFolder(refNum, rootDataFolderHPtr)
int refNum;                              // Not used - always pass zero.
DataFolderHandle* rootDataFolderHPtr;  // Root returned here.
```

Returns a handle to the root data folder of the currently executing Igor thread in *rootDataFolderHPtr.

Data folder handles belong to Igor so you should not modify or dispose them.

The function result is 0 or error code.

Thread Safety

GetRootDataFolder is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

GetCurrentDataFolder

```
int
GetCurrentDataFolder(currentDataFolderHPtr)
DataFolderHandle* currentDataFolderHPtr;  // Current returned here.
```

Returns a handle to the current data folder in *currentFolderHPtr.

Data folder handles belong to Igor so you should not modify or dispose them.

The function result is 0 or error code.

Thread Safety

GetCurrentDataFolder is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

SetCurrentDataFolder

```
int
SetCurrentDataFolder(dataFolderH)
DataFolderHandle dataFolderH;
```

Sets the current data folder to the data folder referenced by dataFolderH.

The function result is 0 or error code.

Thread Safety

SetCurrentDataFolder is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

GetNamedDataFolder

```
int
GetNamedDataFolder(startingDataFolderH, dataFolderPath, dataFolderHPtr)
DataFolderHandle startingDataFolderH;
char dataFolderPath[MAXCMDLEN+1];
DataFolderHandle* dataFolderHPtr;
```

Returns in *dataFolderHPtr the data folder specified by startingDataFolderH and dataFolderPath or NULL if there is no such data folder.

Data folder handles belong to Igor so you should not modify or dispose them.

dataFolderPath can be an absolute path (e.g., "root:FolderA:FolderB:"), a relative path (e.g., ":FolderA:FolderB:") or a data folder name (e.g., "FolderA"). It can also be just ":", a form of relative path that refers to the starting data folder.

If dataFolderPath is an absolute path then startingDataFolderH is immaterial - you can pass any data folder handle or NULL. An absolute path must always start with "root:".

If dataFolderPath is a relative path or a data folder name then dataFolderPath is relative to startingDataFolderH. However, if startingDataFolderH is NULL then dataFolderPath is relative to the current folder.

Absolute and relative paths may include the trailing colon or not, except for the case of root.

Passing "root" as dataFolderPath will not find the root data folder because "root" is a data folder name, not a path. Igor will try to find a data folder named "root" relative to the current data folder. The actual root data folder is never relative to any data folder so it can not be found this way. Use "root:" instead.

Liberal names in dataFolderPath can be quoted or not. Both "root:Folder.1" and "root:'Folder.1'" are acceptable.

The function result is 0 or error code.

Example

```
DataFolderHandle rootH, dataFolderH;
int result;

if (result = GetRootDataFolder(0, &rootH))
   return result;
if (result = GetNamedDataFolder(rootH, ":Packages:", &dataFolderH))
   return result;
```

Thread Safety

GetNamedDataFolder is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

GetDataFolderByIDNumber

```
int
GetDataFolderByIDNumber(IDNumber, dataFolderHPtr)
int IDNumber;
DataFolderHandle* dataFolderHPtr;
```

Returns via *dataFolderHPtr the data folder handle associated with the specified ID number or NULL if there is no such data folder.

Data folder handles belong to Igor so you should not modify or dispose them.

The function result is 0 if OK or a non-zero error code if the data folder doesn't exist, which would be the case if the data folder were killed since you got its ID number.

Data folder ID numbers are valid for data folders in the main thread's data hierarchy only. They are not valid for free root data folders and their descendants or for preemptive thread root data folders and their descendants. See **GetDataFolderIDNumber** for details. The following discussion refers to data folders in the main thread's data hierarchy only.

Each data folder in the main thread's data hierarchy has a unique ID number that stays the same as long as the data folder exists. You can get the ID number for a data folder using **GetDataFolderIDNumber**.

If you need to reference a data folder over a period of time during which it could be killed, then you should store the data folder's ID number. Given the ID number, GetDataFolderByIDNumber tells you if the data folder still exists and, if it does, gives you the data folder handle.

The ID number is valid until the user creates a new Igor experiment or quits Igor. ID numbers are not remembered from one running of Igor to the next.

The function result is 0 or error code.

Thread Safety

GetDataFolderByIDNumber is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

GetParentDataFolder

```
int
GetParentDataFolder(dataFolderH, parentFolderHPtr)
DataFolderHandle dataFolderH;
DataFolderHandle* parentFolderHPtr;
```

Returns the parent of the specified data folder via *parentFolderHPtr.

Data folder handles belong to Igor so you should not modify or dispose them.

If dataFolderH is NULL, GetParentDataFolder uses the current data folder.

Passing the root data folder as dataFolderH is an error. In this case GetParentDataFolder returns NO_PARENT_DATAFOLDER.

If dataFolderH references a free data folder then GetParentDataFolder returns NO_PARENT_DATAFOLDER.

The function result is 0 or error code.

Example

```
// This example shows how to determine if a data folder is free
int dataFolderIsFree = 0;           // Assume not free
if (dfH != GetRootDataFolder()) {
   DataFolderHandle parentDFH;
   if (GetParentDataFolder(dfH,&parentDFH) == NO_PARENT_DATAFOLDER)
      dataFolderIsFree = 1;         // It's free
}
```

Thread Safety

GetParentDataFolder is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

GetNumChildDataFolders

```
int
GetNumChildDataFolders(parentDataFolderH, numChildDataFolderPtr)
DataFolderHandle parentFolderH;
int* numChildDataFolderPtr;
```

Returns the number of child data folders in the specified parent data folder.

If parentDataFolderH is NULL, GetNumChildDataFolders uses the current data folder.

The function result is 0 or error code.

Thread Safety

GetNumChildDataFolders is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

GetIndexedChildDataFolder

```
int
GetIndexedChildDataFolder(parentDataFolderH, index, childDataFolderHPtr)
DataFolderHandle parentFolderH;
int index;                            // 0-based index.
DataFolderHandle* childDataFolderHPtr;
```

Returns via childDataFolderHPtr a handle to the child data folder specified by the index.

Data folder handles belong to Igor so you should not modify or dispose them.

index starts from 0.

If parentDataFolderH is NULL, GetIndexedChildDataFolder uses the current data folder.

The function result is 0 or error code.

Thread Safety

GetIndexedChildDataFolder is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

GetWavesDataFolder

```
int
GetWavesDataFolder(waveH, dataFolderHPtr)
waveHndl waveH;
DataFolderHandle* dataFolderHPtr;
```

Returns via dataFolderHPtr the handle to the data folder containing the specified wave. This will be NULL if the wave is a free wave.

Data folder handles belong to Igor so you should not modify or dispose them.

The function result is 0 or error code.

Thread Safety

GetWavesDataFolder is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

NewDataFolder

```
int
NewDataFolder(parentFolderH, newDataFolderName, newDataFolderHPtr)
DataFolderHandle parentFolderH;
char newDataFolderName[MAX_OBJ_NAME+1];
DataFolderHandle* newDataFolderHPtr;
```

Creates a new data folder in the data folder specified by parentFolderH.

parentFolderH can be a handle to an Igor data folder or NULL to use the current data folder.

You can pass -1 for parentFolderH to create a free data folder. In this case, newDataFolderName is not used but you should still pass a valid C string for it.

On output, *newDataFolderHPtr will contain a handle to the new data folder or NULL if an error occurred.

Data folder handles belong to Igor so you should not modify or dispose them.

NewDataFolder does not change the current data folder. If you want to make the new folder the current folder, call **SetCurrentDataFolder** after NewDataFolder.

The function result is 0 or error code.

Thread Safety

NewDataFolder is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

KillDataFolder

```
int
KillDataFolder(dataFolderH)
DataFolderHandle dataFolderH;
```

Kills an existing data folder, removing it and its contents, including any child data folders, from memory.

dataFolderH is a handle to an existing Igor data folder or NULL to use the current data folder.

You will receive an error and the data folder will not be killed if it contains waves or variables that are in use (e.g., displayed in tables or graphs or used in dependency formulas).

If you kill the current data folder or a data folder that contains the current data folder, Igor will set the current data folder to the parent of the killed data folder.

If you kill the root data folder, its contents will be killed but not the root data folder itself.

NOTE: Once a data folder is successfully killed, dataFolderH is no longer valid. You must not use it again for any purpose.

The function result is 0 or error code.

Thread Safety

KillDataFolder is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

DuplicateDataFolder

```
int
DuplicateDataFolder(sourceDataFolderH,parentDataFolderH,newDataFolderName)
DataFolderHandle sourceDataFolderH;
DataFolderHandle parentDataFolderH;
char newDataFolderName[MAX_OBJ_NAME+1];
```

Creates a clone of the source data folder. The contents of the destination will be clones of the contents of the source.

sourceDataFolderH is a handle to the data folder to be duplicated or NULL to use the current data folder.

parentDataFolderH is a handle to the data folder in which the new data folder is to be created or NULL to use the current data folder.

newDataFolderName is the name to be given to the new data folder.

The function result is 0 or error code.

Thread Safety

DuplicateDataFolder is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

MoveDataFolder

```
int
MoveDataFolder(sourceDataFolderH, newParentDataFolderH)
DataFolderHandle sourceDataFolderH;
DataFolderHandle newParentDataFolderH;
```

Moves the source data folder into a new location in the hierarchy.

It is an error to attempt to move a parent folder into itself or one of its children.

sourceDataFolderH is a handle to the data folder to be moved or NULL to use the current data folder.

newParentDataFolderH is a handle to the data folder in which the source data folder is to be moved or NULL to use the current data folder.

The function result is 0 or error code.

Thread Safety

MoveDataFolder is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

RenameDataFolder

```
int
RenameDataFolder(dataFolderH, newName)
DataFolderHandle dataFolderH;
char newName[MAX_OBJ_NAME+1];
```

Renames the data folder.

dataFolderH is a handle to the data folder to be renamed or NULL to use the current data folder.

The function result is 0 or error code.

Thread Safety

RenameDataFolder is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

GetNumDataFolderObjects

```
int
GetNumDataFolderObjects(dataFolderH, objectType, numObjectsPtr)
DataFolderHandle dataFolderH;
int objectType;
int* numObjectsPtr;
```

Returns via numObjectsPtr the number of objects of the specified type in the specified data folder.

If dataFolderH is NULL, GetNumDataFolderObjects uses the current data folder.

objectType is one of the following:

WAVE_OBJECT	Waves
VAR_OBJECT	Numeric variables
STR_OBJECT	String variables

To find the number of data folders within the data folder, use **GetNumChildDataFolders**.

Thread Safety

GetNumDataFolderObjects is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

GetIndexedDataFolderObject

```
int
GetIndexedDataFolderObject(dataFolderH,objectType,index,objectName,vp)
DataFolderHandle dataFolderH;
int objectType;
int index;
char objectName[MAX_OBJ_NAME+1];
DataObjectValuePtr vp;
```

Returns information that allows you to access an object of the specified type in the specified data folder.

index starts from 0.

If dataFolderH is NULL, GetIndexedDataFolderObject uses the current data folder.

objectType is one of the following:

`WAVE_OBJECT`	Waves
`VAR_OBJECT`	Numeric variables
`STR_OBJECT`	String variables

For information on a data folder, use **GetIndexedChildDataFolder**.

You can pass NULL for objectName if you don't need to know the name of the object.

If you do not want to get the value of the object, pass NULL for vp.

If vp is not NULL, then it is a pointer to a DataObjectValue union, defined in IgorXOP.h. GetIndexedDataFolderObject sets fields depending on the object's type:

`WAVE_OBJECT`	Sets vp->waveH field to wave's handle.
`VAR_OBJECT`	Stores numeric variable's value in vp->nv field.
`STR_OBJECT`	Sets vp->strH field to strings's handle.

The handles returned via the waveH and strH fields belong to Igor. Do not modify or dispose them.

Note that the text in a string handle is *not* null terminated. Use **WMGetHandleSize** to find the number of bytes in the handle. To use C string functions on this text you need to copy it to a local buffer and null-terminate it or add a null terminator to the handle. You must remove the null terminator before control returns to Igor. See **Understand the Difference Between a String in a Handle and a C String** on page 221**.**

The function result is 0 or error code.

Thread Safety

GetIndexedDataFolderObject is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

GetDataFolderObject

```
int
GetDataFolderObject(dataFolderH, objectName, objectTypePtr, vp)
DataFolderHandle dataFolderH;
char objectName[MAX_OBJ_NAME+1];
int* objectTypePtr;
DataObjectValuePtr vp;
```

Returns information about the named object in the specified data folder.

The main utility of this routine will be for getting access to a numeric or string variable in a specific data folder.

If dataFolderH is NULL, GetDataFolderObject uses the current data folder.

On output, if the specified object exists, *objectTypePtr will be one of the following:

`WAVE_OBJECT`	Object is a wave.
`VAR_OBJECT`	Object is a numeric variable.
`STR_OBJECT`	Object is a string variable.
`DATAFOLDER_OBJECT`	Object is a data folder.

If you do not want to get the value of the object, pass NULL for vp.

If vp is not NULL, then it is a pointer to a DataObjectValue union, defined in IgorXOP.h. GetIndexedDataFolderObject sets fields depending on the object's type:

`WAVE_OBJECT`	Sets vp->waveH field to wave's handle.
`VAR_OBJECT`	Stores numeric variable's value in vp->nv field.
`STR_OBJECT`	Sets vp->strH field to string variable's handle.
`DATAFOLDER_OBJECT`	Sets vp->dfH field to data folder's handle.

The handles returned via the waveH, strH and dfH fields belong to Igor. Do not modify or dispose them.

Use these handles immediately and do not store them. Once you return to Igor, Igor can kill the underlying objects.

Note that the text in a string handle is *not* null terminated. Use **WMGetHandleSize** to find the number of bytes in the handle. To use C string functions on this text you need to copy it to a local buffer and null-terminate it or add a null terminator to the handle. You must remove the null terminator before control returns to Igor. See **Understand the Difference Between a String in a Handle and a C String** on page 221**.**

The function result is 0 or error code if there is no object with the specified name.

Example

```
DataObjectValue v;
int objectType;
waveHndl waveH;
Handle strH;
double numVarValue;
DataFolderHandle dfH;
int err;

if (err = GetDataFolderObject(dfH, "AnObject", &objectType, &v))
   return err;

switch(objectType) {
   case WAVE_OBJECT:
      waveH = v.waveH;
      <Do something with waveH>;
      break;

   case VAR_OBJECT:
      numVarValue = v.nv.realValue;
      <Do something with numVarValue>;
      break;

   case STR_OBJECT:
      strH = v.strH;
      <Do something with strH>;
      break;
   case DATAFOLDER_OBJECT:
      dfH = v.dfH;
      <Do something with dfH>;
      break;
}
```

Thread Safety

GetDataFolderObject is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

SetDataFolderObject

```
int
SetDataFolderObject(dataFolderH, objectName, objectType, vp)
DataFolderHandle dataFolderH;
char objectName[MAX_OBJ_NAME+1];
int objectType;
DataObjectValuePtr vp;
```

Sets the value of the named object in the specified data folder.

The main utility of this routine will be for setting the value of a numeric or string variable in a specific data folder.

If dataFolderH is NULL, SetDataFolderObject uses the current data folder.

objectType must be one of the following:

`WAVE_OBJECT`	Wave
`VAR_OBJECT`	Numeric variable
`STR_OBJECT`	String variable
`DATAFOLDER_OBJECT`	Data folder

vp is a pointer to a DataObjectValue union, defined in IgorXOP.h. The action of SetDataFolderObject depends on the object's type:

`WAVE_OBJECT`	Does nothing.
`VAR_OBJECT`	Sets numeric variable to the value in vp->nv field.
`STR_OBJECT`	Sets the string variable to contain the characters in vp->strH.
`DATAFOLDER_OBJECT`	Does nothing.

When setting the value of a string variable, Igor just copies the data from the handle. The handle is yours to dispose (if you created it).

Note that the text in a string handle is *not* null terminated. Use **WMSetHandleSize** to set the number of bytes in the handle. To store a C string in a handle, use **PutCStringInHandle**. See **Understand the Difference Between a String in a Handle and a C String** on page 221**.**

The function result is 0 or error code if there is no object with the specified name.

Example

```
DataObjectValue v;
int objectType;
Handle strH = NULL;
double numVarValue;
DataFolderHandle dfH = NULL;
```

```
int err;

if (err = GetDataFolderObject(dfH, "AnObject", &objectType, &v))
   return err;
switch(objectType) {
   case WAVE_OBJECT:
      break;
   case VAR_OBJECT:
      v.realPart += 1;        // Increment the numeric variable
      break;
   case STR_OBJECT:
      strH = v.strH;          // This handle belongs to Igor.
      if (WMHandToHand(&strH))// Make our own copy.
         return NOMEM;
      if (WMPtrAndHand("***", strH, 3)) {// Append *** to string
         WMDisposeHandle(strH);
         return NOMEM;
      }
      v.strH = strH;          // Used by SetDataFolderObject.
      break;
   case DATAFOLDER_OBJECT:
      break;
}
// Note: SetDataFolderObject does nothing for waves or data folders.
err = SetDataFolderObject(dfH, "AnObject", objectType, &v);
WMDisposeHandle(strH);     // Dispose our copy of handle. (OK if NULL)
return err;
```

Thread Safety

SetDataFolderObject is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

KillDataFolderObject

```
int
KillDataFolderObject(dataFolderH, objectType, objectName)
DataFolderHandle dataFolderH;
int objectType;
char objectName[MAX_OBJ_NAME+1];
```

Kills the named object of the specified type in the specified data folder.

If dataFolderH is NULL, KillDataFolderObject uses the current data folder.

objectType is one of the following:

WAVE_OBJECT	Wave
VAR_OBJECT	Numeric variable
STR_OBJECT	String variable
DATAFOLDER_OBJECT	Data folder

NOTE: If you attempt to kill a wave that is in use (e.g., in a graph, table or dependency formula) the wave will not be killed and you will receive a non-zero result code.

Igor does not check if numeric and string variables are in use. You can kill a numeric or string variable at any time without receiving an error.

The function result is 0 or error code.

Thread Safety

KillDataFolderObject is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

DuplicateDataFolderObject

```
int
DuplicateDataFolderObject(dataFolderH, objectType, objectName,
                              destFolderH, newObjectName, overwrite)
DataFolderHandle dataFolderH;
int objectType;
char objectName[MAX_OBJ_NAME+1];
DataFolderHandle destFolderH;
char newObjectName[MAX_OBJ_NAME+1];
int overwrite;
```

Duplicates the named object of the specified type.

If dataFolderH and/or destFolderH is NULL, DuplicateDataFolderObject uses the current data folder.

objectType is one of the following:

WAVE_OBJECT	Wave
VAR_OBJECT	Numeric variable
STR_OBJECT	String variable
DATAFOLDER_OBJECT	Data folder

If the new name is illegal you will receive a non-zero result code.

If the new name is in use and overwrite is false, you will receive a non-zero result code.

If the new name is in use for a different kind of object, you will receive a non-zero result code.

To avoid these errors, you can check and if necessary fix the new name using **CheckName**, **CleanupName** and **UniqueName2** or the higher-level **CreateValidDataObjectName** routine.

The function result is 0 or error code.

Thread Safety

DuplicateDataFolderObject is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

MoveDataFolderObject

```
int
MoveDataFolderObject(sourceDataFolderH, objectType, objectName,
                                                   destDataFolderH)
DataFolderHandle sourceDataFolderH;
int objectType;
char objectName[MAX_OBJ_NAME+1];
DataFolderHandle destDataFolderH;
```

Moves the named object of the specified type from the source data folder to the destination data folder.

If sourceDataFolderH is NULL, MoveDataFolderObject uses the current data folder.

If destDataFolderH is NULL, MoveDataFolderObject uses the current data folder.

objectType is one of the following:

`WAVE_OBJECT`	Wave
`VAR_OBJECT`	Numeric variable
`STR_OBJECT`	String variable
`DATAFOLDER_OBJECT`	Data folder

NOTE: If an object with the same name exists in the destination data folder, the object will not be moved and you will receive a non-zero result code.

The function result is 0 or error code.

Thread Safety

MoveDataFolderObject is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

RenameDataFolderObject

```
int
RenameDataFolderObject(dataFolderH, objectType, objectName, newObjectName)
DataFolderHandle dataFolderH;
int objectType;
char objectName[MAX_OBJ_NAME+1];
char newObjectName[MAX_OBJ_NAME+1];
```

Renames the named object of the specified type in the specified data folder.

If dataFolderH is NULL, RenameDataFolderObject uses the current data folder.

objectType is one of the following:

`WAVE_OBJECT`	Wave
`VAR_OBJECT`	Numeric variable
`STR_OBJECT`	String variable
`DATAFOLDER_OBJECT`	Data folder

If the new name is illegal or in use the object will not be renamed and you will receive a non-zero result code.

The function result is 0 or error code.

Thread Safety

RenameDataFolderObject is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

HoldDataFolder

```
int
HoldDataFolder(dfH)
DataFolderHandle dfH;
```

Tells Igor that you are holding a reference to a data folder and that the data folder should not be deleted until you call ReleaseDataFolder.

dfH is a data folder handle that you have obtained from Igor.

If dfH is NULL, HoldDataFolder does nothing and returns 0.

See **Data Folder Reference Counting** on page 143 for details.

HoldDataFolder returns an error code as the function result, typically 0 for success or IGOR_OBSOLETE.

Thread Safety

HoldDataFolder is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

ReleaseDataFolder

```
int
ReleaseDataFolder(dfRefPtr)
DataFolderHandle* dfRefPtr;
```

Tells Igor that you are no longer holding a data folder.

dfRefPtr contains the address of your DataFolderHandle variable that refers to a data folder. ReleaseDataFolder sets *dfRefPtr to NULL so your DataFolderHandle variable is not valid after you call ReleaseDataFolder.

If *dfRefPtr is NULL on input then ReleaseDataFolder does nothing and returns 0.

See **Data Folder Reference Counting** on page 143 for details.

ReleaseDataFolder returns an error code as the function result, typically 0 for success or IGOR_OBSOLETE.

Thread Safety

ReleaseDataFolder is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

Routines for XOPs with Menu Items

If your XOP adds one or more menu items to Igor then it must enable and disable them or change them according to circumstances. It must also respond properly when its menu item is selected. These routines allow you to manage your menu items.

See Chapter 8, **Adding Menus and Menu Items**, for an overview.

Most of these routines were added in XOP Toolkit 6.40 to replace ancient routines that were based on the Macintosh Menu Manager. Although these routines were added in XOP Toolkit 6.40, they work with all versions of Igor with minor exceptions.

The old routines were removed from XOP Toolkit 7. If you are updating an existing XOP see ″XOP Menus in XOP Toolkit 7″ in Appendix A of the XOP Toolkit 7 manual.

ResourceToActualMenuID

```
int
ResourceToActualMenuID(resourceMenuID)
int resourceMenuID;
```

Given the ID of a MENU resource in the XOP’s resource fork, ResourceToActualMenuID returns the actual menu ID of that resource in memory.

ResourceToActualMenuID returns 0 if the XOP did not add this menu to Igor.

See **Determining Which Menu Was Chosen** on page 152 for a discussion of resource IDs versus actual IDs.

Thread Safety

ResourceToActualMenuID is not thread-safe.

ActualToResourceMenuID

```
int
ActualToResourceMenuID(menuID)
int menuID;
```

Given the ID of a menu in memory, ActualToResourceMenuID returns the resource ID of the MENU resource in the XOP’s resource fork.

ActualToResourceMenuID returns 0 if the XOP did not add this menu to Igor.

See **Determining Which Menu Was Chosen** on page 152 for a discussion of resource IDs versus actual IDs.

Thread Safety

ActualToResourceMenuID is not thread-safe.

ResourceToActualItem

```
int
ResourceToActualItem(igorMenuID, resourceItemNumber)
int igorMenuID;
int resourceItemNumber;
```

Given the ID of a built-in Igor menu and the number of a menu item specification in the XMI1 resource in the XOP’s resource fork, ResourceToActualItem returns the actual item number of that item in the Igor menu.

Both menu item specification numbers and menu item numbers start from one.

ResourceToActualItem returns 0 if the XOP did not add this menu item to Igor.

See **Determining Which Menu Was Chosen** on page 152 for a discussion of resource items versus actual items.

Thread Safety

ResourceToActualItem is not thread-safe.

ActualToResourceItem

```
int
ActualToResourceItem(igorMenuID, actualItemNumber)
int igorMenuID;
int actualItemNumber;
```

Given the ID of a built-in Igor menu and the actual number of a menu item in the Igor menu, ActualToResourceItem returns the number of the menu item specification in the XMI1 resource in the XOP's resource fork for that item.

Both menu item specification numbers and menu item numbers start from one.

ActualToResourceItem returns 0 if the XOP did not add this menu item to Igor.

See **Determining Which Menu Was Chosen** on page 152 for a discussion of resource items versus actual items.

Thread Safety

ActualToResourceItem is not thread-safe.

SetIgorMenuItem

```
int
SetIgorMenuItem(message, enable, text, param)
int message;              // An Igor message code
int enable;               // 1 to enable the menu item, 0 to disable it
char* text;               // Pointer to a C string or NULL
int param;                // Normally not used and should be 0
```

This routine was used by very advanced XOPs that added target windows to Igor. Adding windows to Igor is no longer supported and use of this routine is no longer recommended. It may be removed in a future version of the XOP Toolkit.

Enables or disables the built-in Igor menu item associated with message.

Call SetIgorMenuItem only if your XOP window is the active window. You would call it in reponse to a MENUENABLE message from Igor.

For example, if the XOP wants to enable the Copy menu item, it would call Igor as follows:

```
if (IsIgorWindowActive((xopWindowRef)) // Is XOP window active?
   SetIgorMenuItem(kXOPWindowMessageCopy, 1, NULL, 0);
```

kXOPWindowMessageCopy is the event message code that would be sent by Igor if the user chose the Copy item in the Edit menu. Event message codes are defined in XOP.h.

The text parameter will normally be NULL. However, there are certain built-in Igor menus whose text can change. An example of this is the Undo item. An XOP which owns the active window can set the Undo item as follows:

```
if (IsIgorWindowActive((xopWindowRef)) // Is XOP window active?
   SetIgorMenuItem(kXOPWindowMessageUndo, 1, "Undo XOP-Specific Action", 0);
```

Igor will ignore the text parameter for menu items whose text is fixed, for example Copy. For menu items whose text is variable, if the text parameter is not NULL, then Igor will set the text of the menu item to the specified text.

The param parameter is currently unused - pass 0 for it.

SetIgorMenuItem returns 1 if there is a menu item corresponding to message or 0 if not. Normally you will have no need for this return value.

Thread Safety

SetIgorMenuItem is not thread-safe.

XOPActualMenuIDToMenuRef

```
XOPMenuRef
XOPActualMenuIDToMenuRef(int actualMenuID)
int actualMenuID;        // The menu ID of a menu that your XOP added to Igor
```

Returns the menu reference for the specified menu.

Use XOPActualMenuIDToMenuRef to get an menu reference for an Igor menu. This is needed to enable or disable an XOP menu item in an Igor menu.

If you are trying to get a menu reference for a menu added to Igor by your XOP use **XOPResourceMenu-IDToMenuRef** instead of XOPActualMenuIDToMenuRef.

Always check the returned menuRef for NULL before using it.

XOPActualMenuIDToMenuRef returns NULL if actualMenuID is not valid.

XOPActualMenuIDToMenuRef returns the menu reference whether the menu is hidden or not.

XOPResourceMenuIDToMenuRef returns your menu reference whether it is hidden or not.

See MenuXOP1.cpp for an example.

Thread Safety

XOPActualMenuIDToMenuRef is not thread-safe.

XOPResourceMenuIDToMenuRef

```
XOPMenuRef
XOPResourceMenuIDToMenuRef(int resourceMenuID)
int resourceMenuID;
```

Given the ID of a MENU resource in the XOP's resource fork, XOPResourceMenuIDToMenuRef returns a reference to the menu. You can use this reference with other XOP menu routines to modify the menu.

Always check the returned menu reference for NULL before using it.

NOTE: XOPResourceMenuIDToMenuRef returns NULL if XOP did not add this menu.

Unlike **XOPActualMenuIDToMenuRef**, XOPResourceMenuIDToMenuRef returns the menu reference even if it is a hidden main menubar menu.

Thread Safety

XOPResourceMenuIDToMenuRef is not thread-safe.

XOPGetMenuInfo

```
int
XOPGetMenuInfo(menuRef, actualMenuID, menuTitle, isVisible, reserved1, reserved2)
XOPMenuRef menuRef;
int* actualMenuID;       // Output
char* menuTitle;         // Output
int* isVisible;          // Output
void* reserved1;         // Reserved for future use - pass NULL
void* reserved2;         // Reserved for future use - pass NULL
```

Returns information about the menu specified by menuRef.

*actualMenuID is set to the actual menu ID of the menu. You can pass NULL if you don't care about this value.

menuTitle is a pointer to a 256 byte array of chars. You can pass NULL if you don't care about this value.

*isVisible is set to the truth that the menu is visible in the menu bar. This returns 0 for hidden main menubar menus and 1 for visible main menubar menus. You can pass NULL if you don't care about this value.

reserved1 and reserved2 are reserved for future use. Pass NULL for these parameters.

The function result is 0 for success or an error code.

See MenuXOP1.cpp for an example.

Thread Safety

XOPGetMenuInfo is not thread-safe.

XOPCountMenuItems

```
int
XOPCountMenuItems(menuRef)
XOPMenuRef menuRef;
```

Returns the number of items in the menu.

See MenuXOP1.cpp for an example.

Thread Safety

XOPCountMenuItems is not thread-safe.

XOPShowMainMenu

```
int
XOPShowMainMenu(menuRef, beforeMenuID)
XOPMenuRef menuRef;
int beforeMenuID;        // The menu ID of a menu in the menubar or 0
```

menuRef is a reference to an XOP main menubar menu. XOPShowMainMenu makes the menu appear in the menubar if it was previously hidden.

beforeMenuID is the actual menu ID of a menu in the menubar or 0 to show the specified menu at the end of the menubar. In most cases you should pass 0.

Returns 0 for success or an error code.

See MenuXOP1.cpp for an example.

Thread Safety

XOPShowMainMenu is not thread-safe.

XOPHideMainMenu

```
int
XOPHideMainMenu(menuRef)
XOPMenuRef menuRef;
```

menuRef is a reference to an XOP main menubar menu. XOPHideMainMenu removes the menu from the menubar if it was previously showing.

Returns 0 for success or an error code.

See MenuXOP1.cpp for an example.

Thread Safety

XOPHideMainMenu is not thread-safe.

XOPGetMenuItemInfo

```
int
XOPGetMenuItemInfo(menuRef, itemNumber, enabled, checked, reserved1, reserved2)
XOPMenuRef menuRef;
int itemNumber;         // A 1-based item number
int* enabled;           // Output - set to 1 if item is enabled, 0 otherwise
int* checked;           // Output - set to 1 if item is checked, 0 otherwise
void* reserved1;        // Reserved for future use - pass NULL
void* reserved2;        // Reserved for future use - pass NULL
```

XOPGetMenuItemInfo returns information about the menu item specified by menuRef and itemNumber.

menuRef is a reference to an XOP menu.

itemNumber is a 1-based item number.

*enabled is set to the truth that the menu item is enabled. You can pass NULL if you don't want to know if the menu item is enabled.

*checked is set to the truth that the menu item is checked. You can pass NULL if you don't want to know if the menu item is checked.

reserved1 and reserved2 are reserved for future use. Pass NULL for these parameters.

Returns 0 for success or an error code.

See MenuXOP1.cpp for an example.

Thread Safety

XOPGetMenuItemInfo is not thread-safe.

XOPGetMenuItemText

```
int
XOPGetMenuItemText(menuRef, itemNumber, text)
XOPMenuRef menuRef;
int itemNumber;         // A 1-based item number
char text[256];         // Item text is returned here
```

XOPGetMenuItemText returns the text from an XOP menu item specified by menuRef and itemNumber.

menuRef is a reference to an XOP menu.

itemNumber is a 1-based item number.

text must be able to hold 255 characters plus the null terminator.

Returns 0 for success or an error code.

See MenuXOP1.cpp for an example.

Thread Safety

XOPGetMenuItemText is not thread-safe.

XOPSetMenuItemText

```
int
XOPSetMenuItemText(menuRef, itemNumber, text)
XOPMenuRef menuRef;
int itemNumber;          // A 1-based item number
const char* text;        // The text for the item
```

XOPSetMenuItemText sets the text of an XOP menu item specified by menuRef and itemNumber.

menuRef is a reference to an XOP menu.

itemNumber is a 1-based item number.

text is C string (null-terminated) of 255 characters or less.

Returns 0 for success or an error code.

See MenuXOP1.cpp for an example.

Thread Safety

XOPSetMenuItemText is not thread-safe.

XOPAppendMenuItem

```
int
XOPAppendMenuItem(menuRef, text)
XOPMenuRef menuRef;
const char* text;        // The text for the item
```

XOPAppendMenuItem adds a menu item to the end of the XOP menu item specified by menuRef.

menuRef is a reference to an XOP menu.

text is C string (null-terminated) of 255 characters or less.

Returns 0 for success or an error code.

See MenuXOP1.cpp for an example.

Thread Safety

XOPAppendMenuItem is not thread-safe.

XOPInsertMenuItem

```
int
XOPInsertMenuItem(menuRef, afterItemNumber, text)
XOPMenuRef menuRef;
int afterItemNumber;     // A 1-based item number
const char* text;        // The text for the item
```

XOPInsertMenuItem inserts a menu item in the XOP menu specified by menuRef.

menuRef is a reference to an XOP menu.

afterItemNumber is a 1-based item number. Pass 0 to insert the menu item at the beginning of the menu. Pass n to insert the item after existing item n of the menu.

text is C string (null-terminated) of 255 characters or less.

Returns 0 for success or an error code.

See MenuXOP1.cpp for an example.

Thread Safety

XOPInsertMenuItem is not thread-safe.

XOPDeleteMenuItem

```
int
XOPDeleteMenuItem(xxx, xxx)
XOPMenuRef menuRef;
int itemNumber;          // A 1-based item number
```

XOPDeleteMenuItem removes the menu item specified by menuRef and itemNumber from an XOP menu.

menuRef is a reference to an XOP menu.

itemNumber is a 1-based item number.

Returns 0 for success or an error code.

See MenuXOP1.cpp for an example.

Thread Safety

XOPDeleteMenuItem is not thread-safe.

XOPDeleteMenuItemRange

```
int
XOPDeleteMenuItemRange(menuRef, firstMenuItemNumber, lastMenuItemNumber)
XOPMenuRef menuRef;
int firstMenuItemNumber;   // A 1-based item number
int lastMenuItemNumber;    // A 1-based item number
```

XOPDeleteMenuItemRange removes a range of menu items from an XOP menu.

menuRef is a reference to an XOP menu.

firstMenuItemNumber and lastMenuItemNumber are 1-based item numbers. They are clipped to the range of valid item numbers so you can pass 1 for firstMenuItemNumber and 10000 for lastMenuItem-Number to delete all items from the menu.

Returns 0 for success or an error code.

See MenuXOP1.cpp for an example.

Thread Safety

XOPDeleteMenuItemRange is not thread-safe.

XOPEnableMenuItem

```
int
XOPEnableMenuItem(menuRef, itemNumber)
XOPMenuRef menuRef;
int itemNumber;          // A 1-based item number
```

XOPEnableMenuItem enables the specified item.

menuRef is a reference to an XOP menu or an Igor menu.

itemNumber is a 1-based item number.

Returns 0 for success or an error code.

See MenuXOP1.cpp for an example.

Thread Safety

XOPEnableMenuItem is not thread-safe.

XOPDisableMenuItem

```
int
XOPDisableMenuItem(menuRef, itemNumber)
XOPMenuRef menuRef;
int itemNumber;         // A 1-based item number
```

XOPDisableMenuItem disables the specified item.

menuRef is a reference to an XOP menu or an Igor menu.

itemNumber is a 1-based item number.

Returns 0 for success or an error code.

See MenuXOP1.cpp for an example.

Thread Safety

XOPDisableMenuItem is not thread-safe.

XOPCheckMenuItem

```
int
XOPCheckMenuItem(menuRef, itemNumber, state)
XOPMenuRef menuRef;
int itemNumber;         // A 1-based item number
int state;              // 1 for check, 0 for uncheck
```

XOPCheckMenuItem adds or removes a checkmark from a menu item.

menuRef is a reference to an XOP menu or an Igor menu.

itemNumber is a 1-based item number.

Returns 0 for success or an error code.

See MenuXOP1.cpp for an example.

Thread Safety

XOPCheckMenuItem is not thread-safe.

XOPFillMenu

```
void
XOPFillMenu(menuRef, afterItemNumber, itemList)
XOPMenuRef menuRef;     // A reference to an XOP menu
int afterItemNumber;    // A 1-based item number of an item in the menu
const char* itemList;   // Semicolon separated list of items to add to menu
```

itemList is C string (null-terminated) containing a semicolon separated list of items to be put into the menu.

afterItemNumber specifies where the items in itemList are to appear in the menu.

afterItemNumber = 0	New items appear at beginning of menu
afterItemNumber = 10000	New items appear at end of menu
afterItemNumber = item number	New items appear after specified existing item number

XOPFillMenu supports Macintosh menu manager meta-characters in menu items. For example, if a "(" character appears in the item list, it will not be displayed in the corresponding menu item but instead will cause the item to be disabled. Use XOPFillMenuNoMeta if you don’t want this behavior.

Returns 0 or an error code.

Thread Safety

XOPFillMenu is not thread-safe.

XOPFillMenuNoMeta

```
void
XOPFillMenuNoMeta(menuRef, afterItemNumber, itemList)
XOPMenuRef menuRef;      // A reference to an XOP menu
int afterItemNumber;     // A 1-based item number of an item in the menu
const char* itemList;    // Semicolon separated list of items to add to menu
```

XOPFillMenuNoMeta works exactly like XOPFillMenu except that it does not honor meta-characters.

itemList is C string (null-terminated) containing a semicolon separated list of items to be put into the menu.

afterItemNumber specifies where the items in itemList are to appear in the menu.

afterItemNumber = 0	New items appear at beginning of menu
afterItemNumber = 10000	New items appear at end of menu
afterItemNumber = item number	New items appear after specified existing item number

Returns 0 or an error code.

Thread Safety

XOPFillMenuNoMeta is not thread-safe.

XOPFillWaveMenu

```
int
XOPFillWaveMenu(menuRef, match, options, afterItemNumber)
XOPMenuRef menuRef;      // A reference to an XOP menu
char* match;             // "*" for all waves or match pattern
char* options;           // Options for further selection of wave
int afterItemNumber;     // A 1-based item number of an item in the menu
```

Fills the menu with wave names selected based on match and options.

The added items are added after the item specified by afterItemNumber or, if afterItemNumber is 0, at the beginning of the menu.

The meaning of the match, and options parameters is the same as for the built-in Igor WaveList function.

XOPFillWaveMenu does not treat any characters as meta-characters.

Returns 0 or an error code.

Thread Safety

XOPFillWaveMenu is not thread-safe.

XOPFillPathMenu

```
int
XOPFillPathMenu(menuRef, match, options, afterItemNumber)
XOPMenuRef menuRef;      // A reference to an XOP menu
char* match;             // "*" for all paths or match pattern
char* options;           // Options for further selection of path
int afterItemNumber;     // A 1-based item number of an item in the menu
```

Fills the menu with path names selected based on match.

The added items are added after the item specified by afterItemNumber or, if afterItemNumber is 0, at the beginning of the menu.

The meaning of the match parameter is the same as for the built-in Igor PathList function.

options must be "".

Returns 0 or an error code.

XOPFillPathMenu does not treat any characters as meta-characters.

Thread Safety

XOPFillPathMenu is not thread-safe.

XOPFillWinMenu

```
int
XOPFillWinMenu(menuRef, match, options, afterItemNumber)
XOPMenuRef menuRef;      // A reference to an XOP menu
char* match;             // "*" for all windows or match pattern
char* options;           // Options for further selection of windows
int afterItemNumber;     // A 1-based item number of an item in the menu
```

Fills the menu with Igor target window names selected based on match and options.

The added items are added after the item specified by afterItemNumber or, if afterItemNumber is 0, at the beginning of the menu.

The meaning of the match parameter is the same as for the built-in Igor WinList function.

If options is "" then all windows are selected.

If options is "WIN:" then just the target window is selected.

If options is "WIN:typeMask" then windows of the specified types are selected.

The window type masks are defined in IgorXOP.h. For example, "WIN:1" selects graph windows only. "WIN:3" selects graphs and tables.

Returns 0 or an error code.

XOPFillWinMenu does not treat any characters as meta-characters.

Thread Safety

XOPFillWinMenu is not thread-safe.

Routines for XOPs that Have Dialogs

Most dialog-related XOPSupport routines were removed in XOP Toolkit 7. If you are porting an old XOP that implements a dialog, see "XOP Dialogs in XOP Toolkit 7" in Appendix A of the XOP Toolkit 7 manual for details.

For background information on adding dialogs in an XOP, see **Adding Dialogs** on page 192.

FinishDialogCmd

```
void
FinishDialogCmd(cmd, mode)
char* cmd;                  // C string containing command
int mode;
```

You call FinishDialogCmd at end of an Igor-style dialog.

cmd is a null-terminated C string containing the command generated by the Igor-style dialog.

If mode is 1, FinishDialogCmd puts the command in Igor's command line and starts execution.

If mode is 2, FinishDialogCmd puts the command in Igor's command line but does not start execution.

If mode is 3, FinishDialogCmd puts the command in the clipboard.

Liberal names of waves and data folders must be quoted before using them in the Igor command line. Use **PossiblyQuoteName** when preparing the command to be executed so that your XOP works with liberal names.

Thread Safety

FinishDialogCmd is not thread-safe.

Routines for XOPs that Access Files

These routines assist an XOP in opening and saving files and in reading data from and writing data to files in a platform-independent way. For an overview, see **File I/O** on page 187.

Some of these routines use full paths to identify files. The full paths must be “native”.

On Macintosh, “native” means “HFS” (Hierarchical File System) which means that the path separator is a colon. Do not use POSIX paths (with forward slashes) because the Carbon routines called by the XOPSupport routines do not support forward slashes.

On Windows, “native” means that the path separator is a backslash.

MacToWinPath

```
int
MacToWinPath(path)
char path[MAX_PATH_LEN+1];
```

MacToWinPath handles file path format conversion for cross-platform XOPs. See **File Path Conversions** on page 188 for background information.

MacToWinPath converts a Macintosh HFS path into a Windows path by replacing 'X:' with 'X:\' at the start of a full path and replacing ':' with '\' elsewhere. Also, leading colons are changed to periods. However, it does not change a UNC volume name. Here are examples of the conversion performed by MacToWinPath.

```
C:A:B:C                 ->      C:\A\B\C
\\server\share:A:B:C ->      \\server\share\A\B\C
"::FolderA:FileB"       ->      "..\FolderA\FileB"
```

In the first example, the volume name is "C". In the second example, using a UNC path, the volume name is "\\server\share".

If the path is already a Windows path, MacToWinPath does nothing.

The following characters are illegal in Windows file names and are considered illegal by Igor. For cross-platform compatibility, you should not use them:

```
\  /  :  *  ?  "  <  >  |  <All control characters>
```

Control characters are characters whose ASCII codes are less than 32 decimal (20 hexadecimal).

NOTE: The path may be longer on output than in was on input ('C:' changed to 'C:\' or ':' changed to '.\'). The buffer is assumed to be MAX_PATH_LEN+1 characters long. MacToWin-Path will not overwrite the buffer. It will generate an error if the output path can not fit in MAX_PATH_LEN characters.

When running on an Asian language system, MacToWinPath is double-byte-character-aware and assumes that the system default character encoding governs the path.

The function result is 0 if OK or an error code, such as PATH_TOO_LONG.

Thread Safety

MacToWinPath is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

WinToMacPath

```
int
WinToMacPath(path)
char path[MAX_PATH_LEN+1];
```

WinToMacPath handles file path format conversion for cross-platform XOPs. See **File Path Conversions** on page 188 for background information.

WinToMacPath converts a Windows path into a Macintosh HFS path by replacing ':\' with ':' at the start of a full path and replacing '\' with ':' elsewhere. Also, leading periods are changed to colons. However, it does not change a UNC volume name. Here are examples of the conversion performed by WinToMacPath.

```
C:\A\B\C               ->       C:A:B:C
\\server\share\A\B\C ->       \\server\share:A:B:C
"..\FolderA\FileB"     ->       "::FolderA:FileB"
```

In the first example, the volume name is "C". In the second example, using a UNC path, it is "\\server\share".

If the path is already a Macintosh HFS path, MacToWinPath does nothing.

The following characters are illegal in Windows file names and are considered illegal by Igor. For cross-platform compatibility, you should not use them:

```
\  /  :  *  ?  "  <  >  |  <All control characters>
```

Control characters are characters whose ASCII codes are less than 32 decimal (20 hexadecimal).

NOTE: The path may be shorter on output than in was on input (':\' or '.\' changed to ':').

When running on an Asian language system, WinToMacPath is double-byte-character-aware and assumes that the system default character encoding governs the path.

The function result is 0 if OK or an error code.

Thread Safety

WinToMacPath is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

HFSToPosixPath

```
int
HFSToPosixPath(hfsPath, posixPath[MAX_PATH_LEN+1], isDirectory)
const char* hfsPath;
char posixPath[MAX_PATH_LEN+1];
int isDirectory;
```

Converts an HFS (colon-separated) path into a POSIX (Unix-style) path. This is available only on MacOS and only to convert paths into POSIX paths so that we can pass them to the standard file fopen routine or to OS routines that require POSIX paths.

From the point of view of the Igor user, all paths should be HFS paths although Windows paths are accepted and converted when necessary. POSIX paths are not valid paths in Igor procedures.

It is allowed for hfsPath and posixPath to point to the same memory.

hfsPath is assumed to be encoded as UTF-8.

posixPath is encoded as UTF-8.

Returns 0 if OK or an error code. If an error is returned, *posixPath is undefined.

Thread Safety

HFSToPosixPath is thread-safe. It can be called from any thread.

GetNativePath

```
int
GetNativePath(filePathIn, filePathOut)
char filePathIn[MAX_PATH_LEN+1];
char filePathOut[MAX_PATH_LEN+1];
```

GetNativePath handles file path format conversion for cross-platform XOPs. See **File Path Conversions** on page 188 for background information.

GetNativePath copies filePathIn to filePathOut and then calls **WinToMacPath** when running on Macintosh and **MacToWinPath** when running on Windows. If filePathIn does not use the conventions of the current platform, it converts filePathOut to use those conventions.

filePathOut can point to the same memory as filePathIn or it can point to different memory.

When running on an Asian language system, GetNativePath is double-byte-character-aware and assumes that the system default character encoding governs the path.

The function result is 0 if OK or an error code.

Thread Safety

GetNativePath is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

ConcatenatePaths

```
int
ConcatenatePaths(pathIn1, nameOrPathIn2, pathOut)
const char* pathIn1;
const char* nameOrPathIn2;
char pathOut[MAX_PATH_LEN+1];
```

Concatenates pathIn1 and nameOrPathIn2 into pathOut.

pathOut will be a native path. The input paths may use Macintosh or Windows conventions. See **File Path Conversions** on page 188 for background information.

pathIn1 is a full path to a directory. It can end with zero or one separator.

nameOrPathIn2 is either a file name, a folder name or a partial path to a file or folder. It can end with zero or one separator.

pathOut can point to the same memory as either of the input parameters.

The target file or folder does not need to already exist.

For pathIn1, any of the following are legal.

```
"hd:FolderA:FolderB"     "hd:FolderA:FolderB:"
"C:\FolderA\FolderB"     "C:\FolderA\FolderB\"
```

For nameOrPathIn2, any of the following are legal.

```
"FileA"                  "FolderC"
":FolderC"               "\FolderC"
".FolderC"                                    // Legal in a Windows path only
"::FolderC"              "\\FolderC"
"..FolderC"                                   // Legal in a Windows path only
"FolderC:FileA"          "FolderC\FileA"
"\FolderC:FileA"         "\FolderC\FileA"
```

Here are some examples of concatenation.

```
"hd:FolderA:FolderB:"   +  "FolderC"   ->    "hd:FolderA:FolderB:FolderC"
"hd:FolderA:FolderB:"   +  ":FolderC"  ->    "hd:FolderA:FolderB:FolderC"
```

```
"hd:FolderA:FolderB:"   +  "::FolderC" ->    "hd:FolderA:FolderC"
"C:\FolderA\FolderB\"   +  "FolderC"   ->    "C:\FolderA\FolderB\FolderC"
"C:\FolderA\FolderB\"   +  "\FolderC"  ->    "C:\FolderA\FolderB\FolderC"
"C:\FolderA\FolderB\"   +  "\\FolderC" ->    "C:\FolderA\FolderC"
```

Multiple colons or backslashes in nameOrPathIn2 mean that we want to back up, starting from the folder specified by pathIn1.

When running on an Asian language system, ConcatenatePaths is double-byte-character-aware and assumes that the system default character encoding governs the paths.

The function result is 0 or error code. In case of error, the contents of pathOut is undefined.

Thread Safety

ConcatenatePaths is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

GetDirectoryAndFileNameFromFullPath

```
int
GetDirectoryAndFileNameFromFullPath(fullFilePath, dirPath, fileName)
const char* fullFilePath;
char dirPath[MAX_PATH_LEN+1];
char fileName[MAX_FILENAME_LEN+1];
```

fullFilePath is a full path to a file. It may be a Macintosh HFS path (using colons) or a Windows path (using backslashes).

On output, dirPath is the full native path to the folder containing the file. This path includes a trailing colon (Macintosh) or backslash (Windows).

On output, fileName contains just the name of the file.

The function result is 0 if OK or an error code.

GetDirectoryAndFileNameFromFullPath does not know or care if the file exists or if the directories referenced in the input path exist. It merely separates the file name part from the full path.

Thread Safety

GetDirectoryAndFileNameFromFullPath is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

FullPathPointsToFile

```
int
FullPathPointsToFile(fullPath)
const char* fullPath;
```

Returns 1 if the path points to an existing file, 0 if it points to a folder or does not point to anything.

fullPath may be a Macintosh or a Windows path.

When running on an Asian language system, FullPathPointsToFile is double-byte-character-aware and assumes that the system default character encoding governs the path.

Thread Safety

FullPathPointsToFile is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

FullPathPointsToFolder

```
int
FullPathPointsToFolder(fullPath)
const char* fullPath;
```

Returns 1 if the path points to an existing folder, 0 if it points to a file or does not point to anything.

fullPath may be a Macintosh or a Windows path.

When running on an Asian language system, FullPathPointsToFolder is double-byte-character-aware and assumes that the system default character encoding governs the path.

Thread Safety

FullPathPointsToFolder is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

GetLeafName

```
int
GetLeafName(filePath, leafName)
const char* filePath;
char leafName[MAX_FILENAME_LEN+1];
```

filePath is either "", a valid file name or a valid path to a file.

leafName must be able to hold MAX_FILENAME_LEN+1 bytes.

GetLeafName returns via leafName the leaf part of the path if it is a path or the contents of filePath if is not a path.

Returns 0 if OK or an error code.

Thread Safety

GetLeafName is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

ParseFilePath

```
int
ParseFilePath(mode, pathIn, separator, whichEnd, whichElement, pathOut)
int mode;
const char* pathIn;
const char* separator;
int whichEnd, whichElement;
char pathOut[MAX_PATH_LEN+1];
```

The ParseFilePath function provides the ability to manipulate file paths and to extract sections of file paths.

This XOPSupport routine works the same as the Igor built-in ParseFilePath function.

For further explanation, see the documentation for ParseFilePath in the Igor Reference help file.

The output is returned via the pathOut parameter which must be able to hold MAX_PATH_LEN+1 bytes.

The function result is 0 for success or an Igor error code.

Thread Safety

ParseFilePath is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

SpecialDirPath

```
int
SpecialDirPath(pathID, domain, flags, createDir, pathOut)
const char* pathID;
int domain, flags, createDir;
char pathOut[MAX_PATH_LEN+1];
```

The SpecialDirPath function returns a full path to a file system directory specified by pathID and domain. It provides a programmer with a way to access directories of special interest, such as the preferences directory, the Igor Pro User Files directory and the desktop directory.

This XOPSupport routine works the same as the Igor built-in SpecialDirPath function.

For further explanation, see the documentation for SpecialDirPath in the Igor Reference help file.

The output is returned via the pathOut parameter which must be able to hold MAX_PATH_LEN+1 bytes.

The function result is 0 for success or an Igor error code.

Thread Safety

SpecialDirPath is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

XOPCreateFile

```
int
XOPCreateFile(fullFilePath, overwrite, macCreator, macFileType)
const char* fullFilePath;
int overwrite;
int macCreator;
int macFileType;
```

Creates a file with the location and name specified by fullFilePath.

fullFilePath must be an HFS path (using colon separators) on Macintosh and a Windows path (using backslashes) on Windows.

If overwrite is true and a file by that name already exists, it first deletes the conflicting file. If overwrite is false and a file by that name exists, it returns an error.

macFileType is ignored on Windows. On Macintosh, it is used to set the new file's type. For example, use 'TEXT' for a text file.

macCreator is ignored on Windows. On Macintosh, it is used to set the new file's creator code. For example, use 'IGR0' (last character is zero) for an file.

Returns 0 if OK or an error code.

Thread Safety

XOPCreateFile is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

XOPDeleteFile

```
int
XOPDeleteFile(fullFilePath)
const char* fullFilePath;
```

Deletes the specified file.

fullFilePath must be an HFS path (using colon separators) on Macintosh and a Windows path (using backslashes) on Windows.

Returns 0 if OK or an error code.

Thread Safety

XOPDeleteFile is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

XOPOpenFile

```
int
XOPOpenFile(fullFilePath, readOrWrite, fileRefPtr)
const char* fullFilePath;
int readOrWrite;
XOP_FILE_REF* fileRefPtr;
```

If readOrWrite is zero, opens an existing file for reading and returns a file reference via fileRefPtr.

If readOrWrite is non-zero, opens an existing file for writing or creates a new file if none exists and returns a file reference via fileRefPtr.

fullFilePath must be an HFS path (using colon separators) on Macintosh and a Windows path (using backslashes) on Windows.

The function result is 0 if OK or an error code.

Thread Safety

XOPOpenFile is thread-safe. It can be called from any thread.

XOPCloseFile

```
int
XOPCloseFile(XOP_FILE_REF fileRef)
XOP_FILE_REF fileRef;            // Reference returned by XOPOpenFile
```

Closes the referenced file.

XOPCloseFile returns 0 if OK or an error code.

Thread Safety

XOPCloseFile is thread-safe. It can be called from any thread.

XOPReadFile

```
int
XOPReadFile(fileRef, count, buffer, numBytesReadPtr)
XOP_FILE_REF fileRef;            // Reference returned by XOPOpenFile
UInt32 count;                    // Count of bytes to read
void* buffer;                    // Where bytes are stored
UInt32* numBytesReadPtr;         // Output: number of bytes read
```

Reads count bytes from the referenced file into the buffer.

If numBytesReadPtr is not NULL, XOPReadFile stores the number of bytes read in *numBytesReadPtr.

The function result is 0 if OK or an error code.

If bytes remain to be read in the file and you ask to read more bytes than remain, the remaining bytes are returned and the function result is zero. If no bytes remain to be read in the file and you ask to read bytes, no bytes are returned and the function result is FILE_EOF_ERROR.

XOPReadFile is appropriate when you are reading data of variable size, in which case you do not want to consider it an error if the end of file is reached before reading all of the bytes that you requested. If you are reading a record of fixed size, use use **XOPReadFile2** instead of XOPReadFile.

Thread Safety

XOPReadFile is thread-safe. It can be called from any thread.

XOPReadFile2

```
int
XOPReadFile2(fileRef, count, buffer, numBytesReadPtr)
XOP_FILE_REF fileRef;            // Reference returned by XOPOpenFile
UInt32 count;                    // Count of bytes to read
void* buffer;                    // Where bytes are stored
UInt32* numBytesReadPtr;         // Output: number of bytes read
```

Reads count bytes from the referenced file into the buffer.

If numBytesReadPtr is not NULL, XOPReadFile2 stores the number of bytes read in *numBytesReadPtr.

The function result is 0 if OK or an error code.

If bytes remain to be read in the file and you ask to read more bytes than remain, the remaining bytes are returned and the function result is FILE_EOF_ERROR.

XOPReadFile2 is appropriate when you are reading a record of fixed size, in which case you want to consider it an error if the end of file is reached before reading all of the bytes in the record. If you are reading a record of variable size then you should use **XOPReadFile** instead of XOPReadFile2.

Thread Safety

XOPReadFile2 is thread-safe. It can be called from any thread.

XOPReadFile64

```
int
XOPReadFile64(fileRef, count, buffer, numBytesReadPtr)
XOP_FILE_REF fileRef;            // Reference returned by XOPOpenFile
SInt64 count;                    // Count of bytes to read
void* buffer;                    // Where bytes are stored
SInt64* numBytesReadPtr;         // Output: number of bytes read
```

Reads count bytes from the referenced file into the buffer.

Use XOPReadFile64 when you need to read potentially greater than 4GB in one read call. When called from a 32-bit XOP, XOPReadFile64 is limited to 4GB and returns an error if count is greater than 4GB.

If numBytesReadPtr is not NULL, XOPReadFile64 stores the number of bytes read in *numBytesReadPtr.

The function result is 0 if OK or an error code.

If bytes remain to be read in the file and you ask to read more bytes than remain, the remaining bytes are returned and the function result is FILE_EOF_ERROR.

Thread Safety

XOPReadFile64 is thread-safe. It can be called from any thread.

XOPReadLine

```
int
XOPReadLine(fileRef, buffer, bufferLength, numBytesReadPtr)
XOP_FILE_REF fileRef;            // Reference returned by XOPOpenFile
char* buffer;                    // Where bytes are stored
UInt32 bufferLength;             // Size of the buffer in bytes
UInt32* numBytesReadPtr;         // Output: number of bytes read
```

Reads a line of text from the file into the buffer.

buffer points to a buffer into which the line of data is to be read. bufferLength is the size of the buffer. The buffer can hold bufferLength-1 characters, plus the terminating null character.

A line in the file may end with:

```
<end-of-file>
CR
LF
CRLF
```

XOPReadLine reads the next line of text into the buffer and null-terminates it. The terminating CR, LF, or CRLF is not stored in the buffer.

If numBytesReadPtr is not NULL, XOPReadLine stores the number of bytes read in *numBytesReadPtr.

The function result will be LINE_TOO_LONG_IN_FILE if there is not enough room in the buffer to read the entire line. It will be FILE_EOF_ERROR if we hit the end-of-file before reading any characters. It will be zero if we read any characters (even just a CR or LF) before hitting the end of the file.

XOPReadLine was designed for simplicity of use. For applications that require blazing speed (e.g., reading files containing tens of thousands of lines or more), a more complex buffering scheme can improve performance considerably.

Thread Safety

XOPReadLine is thread-safe. It can be called from any thread.

XOPWriteFile

```
int
XOPWriteFile(fileRef, count, buffer, numBytesWrittenPtr)
XOP_FILE_REF fileRef;              // Reference returned by XOPOpenFile
UInt32 count;                      // Count of bytes to write
const void* buffer;                // Pointer to data to write
UInt32* numBytesWrittenPtr;        // Output: number of bytes written
```

Writes count bytes from the buffer to the referenced file.

If numBytesWrittenPtr is not NULL, XOPWriteFile stores the number of bytes written in *numBytesWrittenPtr.

The function result is 0 if OK or an error code.

Thread Safety

XOPWriteFile is thread-safe. It can be called from any thread.

XOPWriteFile64

```
int
XOPWriteFile64(fileRef, count, buffer, numBytesWrittenPtr)
XOP_FILE_REF fileRef;              // Reference returned by XOPOpenFile
SInt64 count;                      // Count of bytes to write
const void* buffer;                // Pointer to data to write
SInt64* numBytesWrittenPtr;        // Output: number of bytes written
```

Writes count bytes from the buffer to the referenced file.

Use XOPWriteFile64 when you need to write potentially greater than 4GB in one write call. When called from a 32-bit XOP, XOPWriteFile64 is limited to 4GB and returns an error if count is greater than 4GB.

If numBytesWrittenPtr is not NULL, XOPWriteFile64 stores the number of bytes written in *numBytesWrittenPtr.

The function result is 0 if OK or an error code.

Thread Safety

XOPWriteFile64 is thread-safe. It can be called from any thread.

XOPGetFilePosition

```
int
XOPGetFilePosition(fileRef, filePosPtr)
XOP_FILE_REF fileRef;               // Reference returned by XOPOpenFile
UInt32* filePosPtr;
```

Returns via filePosPtr the current file position of the referenced file.

The function result is 0 if OK or an error code.

If the file size may exceed 2 GB, use **XOPGetFilePosition2** instead of XOPGetFilePosition.

Thread Safety

XOPGetFilePosition is thread-safe. It can be called from any thread.

XOPGetFilePosition2

```
int
XOPGetFilePosition2(fileRef, dFilePosPtr)
XOP_FILE_REF fileRef;      // Reference returned by XOPOpenFile
SInt64* filePosPtr;
```

Returns via filePosPtr the current file position of the referenced file.

XOPGetFilePosition2 is the same as XOPGetFilePosition except that the file position parameter is an SInt64* rather than a UInt32* and it works with files larger than 2 GB.

The function result is 0 if OK or an error code.

Thread Safety

XOPGetFilePosition2 is thread-safe. It can be called from any thread.

XOPSetFilePosition

```
int
XOPSetFilePosition(fileRef, filePos, mode)
XOP_FILE_REF fileRef;      // Reference returned by XOPOpenFile
SInt32 filePos;
int mode;
```

Sets the current file position in the referenced file.

If mode is -1, then filePos is relative to the start of the file. If mode is 0, then filePos is relative to the current file position. If mode is 1, then filePos is relative to the end of the file.

The function result is 0 if OK or an error code.

If the file size may exceed 2 GB, use **XOPSetFilePosition2** instead of XOPSetFilePosition.

Thread Safety

XOPSetFilePosition is thread-safe. It can be called from any thread.

XOPSetFilePosition2

```
int
XOPSetFilePosition2(fileRef, dFilePos)
XOP_FILE_REF fileRef;       // Reference returned by XOPOpenFile
SInt64 filePos;
```

Sets the current file position in the referenced file.

filePos is relative to the start of the file.

XOPSetFilePosition2 is the same as XOPSetFilePosition except that the file position parameter is an SInt64 rather than an SInt32 and it works with files larger than 2 GB and also it is lacking the mode parameter.

The function result is 0 if OK or an error code.

Thread Safety

XOPSetFilePosition2 is thread-safe. It can be called from any thread.

XOPAtEndOfFile

```
int
XOPAtEndOfFile(fileRef)
XOP_FILE_REF fileRef;       // Reference returned by XOPOpenFile
```

Returns 1 if the current file position is at the end of file, 0 if not.

Thread Safety

XOPAtEndOfFile is thread-safe. It can be called from any thread.

XOPNumberOfBytesInFile

```
int
XOPNumberOfBytesInFile(fileRef, numBytesPtr)
XOP_FILE_REF fileRef;       // Reference returned by XOPOpenFile
UInt32* numBytesPtr;
```

Returns via numBytesPtr the total number of bytes in the referenced file.

The function result is 0 if OK or an error code.

If the file size may exceed 4 GB, use **XOPNumberOfBytesInFile2** instead of XOPNumberOfBytesInFile.

Thread Safety

XOPNumberOfBytesInFile is thread-safe. It can be called from any thread.

XOPNumberOfBytesInFile2

```
int
XOPNumberOfBytesInFile2(fileRef, dNumBytesPtr)
XOP_FILE_REF fileRef;       // Reference returned by XOPOpenFile
SInt64* numBytesPtr;
```

Returns via numBytesPtr the total number of bytes in the referenced file.

XOPNumberOfBytesInFile2 is the same as XOPNumberOfBytesInFile except that the numBytesPtr parameter is an SInt64* rather than a UInt32* and it works with files larger than 4 GB.

The function result is 0 if OK or an error code.

Thread Safety

XOPNumberOfBytesInFile2 is thread-safe. It can be called from any thread.

XOPOpenFileDialog

```
int
XOPOpenFileDialog(prompt, fileFilterStr, indexPtr, initDir, fullFilePath)
const char* prompt;                  // Message displayed in dialog
const char* fileFilterStr;           // Controls types of files shown
int* indexPtr;                       // Controls initial type of file shown
const char* initDir;                 // Sets initial directory
char fullFilePath[MAX_PATH_LEN+1];   // Output path returned here
```

XOPOpenFileDialog is obsolescent. Use **XOPOpenFileDialog2** instead of XOPOpenFileDialog.

Displays the Open File dialog.

XOPOpenFileDialog returns 0 if the user chooses a file or -1 if the user cancels or another non-zero number in the event of an error.

XOPOpenFileDialog returns the full path to the file via fullFilePath. In the event of a cancel, fullFilePath is unmodified.

fullFilePath is a native path (using colons on Macintosh, backslashes on Windows).

prompt sets the dialog window title.

If fileFilterStr is "", then the open file dialog displays all types of files, both on Macintosh and Windows. If fileFilterStr is not "", it identifies the type of files to display.

fileFilterStr on Macintosh

fileFilterStr provides control over the Enable popup menu which the Macintosh Navigation Manager displays in the Open File dialog. For example, the string:

```
   "Text Files:TEXT,IGTX:.txt,.itx;All Files:****:;"
```

results in two items in the Enable popup menu.

The two section sections of this fileFilterString are:

```
   "Text Files:TEXT,IGTX:.txt,.itx;"
   "All Files:****:;"
```

Each section causes the creation of one item in the Enable popup menu.

Each section consists of three components: a menu item string to be displayed in the Enable popup menu, a list of zero or more Macintosh file types (e.g., TEXT,IGTX), and a list of extensions (e.g., .txt,.itx).

In this example, the first menu item would be "Text Files". When the user selects this menu item, the Open File dialog would show any file whose Macintosh file type is TEXT or IGTX and any file whose extension is .txt, or .itx.

Note that a colon marks the end of the menu item string, another colon marks the end of the list of Macintosh file types, and a semicolon marks the end of the list of extensions.

The **** file type used in the second section is special. It means that the Open File dialog should display all files. In this section, no extensions are specified because there are no characters between the colon and the semicolon.

The syntax of the fileFilterString is unforgiving. You must not use any extraneous spaces or any other extraneous characters. You must include the colons and semicolons as shown above. The trailing semicolon is required. If there is a syntax error, the entire fileFilterString will be treated as if it were empty, which will display all files.

fileFilterStr on Windows

On Windows, fileFilterStr is constructed as for the lpstrFilter field of the OPENFILENAME structure for the Windows GetOpenFileName routine. For example, to allow the user to select text files and Igor Text files, use:

```
"Text Files (*.txt)\0*.txt\0Igor Text Files (*.itx)\0*.itx\0
```

```
                                      All Files (*.*)\0*.*\0\0"
```

This would all be on one line in an actual program. Note that the string ends with two null characters (\0\0).

On Windows you can specify multiple extensions for a single type of file by listing the extensions with a semicolon between them. For example:

```
"Excel Files (*.xls,*.xlsx)\0*.xls;*.xlsx\0All Files (*.*)\0*.*\0\0");
```

fileIndexPtr is ignored if it is NULL. If it is not NULL, then *fileIndexPtr is the one-based index of the file type filter to be initially selected. In the example given above, setting *fileIndexPtr to 2 would select the Igor Text file filter on entry to the dialog. On exit from the dialog, *fileIndexPtr is set to the index of the file filter string that the user last selected.

initialDir can be "" or it can point to a full path to a directory. It determines the directory that will be initially displayed in the Open File or Save File dialogs. If it is "", the directory will be the last directory that was seen in the open or save file dialogs. If initialDir points to a valid path to a directory, then this directory will be initially displayed in the dialog. initialDir is a native path (using colons on Macintosh, backslashes on Windows).

XOPOpenFileDialog returns via fullFilePath the full path to the file that the user chose. It is unchanged if the user cancels. The path is native path (using colons on Macintosh, backslashes on Windows). fullFilePath must point to a buffer of at least MAX_PATH_LEN+1 bytes.

On Windows, the initial value of fullFilePath sets the initial contents of the File Name edit control in the Open File dialog. The following values are valid:

```
   ""
   A file name
   A full Macintosh or Windows path to a file
```

On Macintosh, the initial value of fullFilePath is not currently used. It should be set the same as for Windows because it may be used in the future.

In the event of an error other than a cancel, XOPOpenFileDialog displays an error dialog. This should never or rarely happen.

Thread Safety

XOPOpenFileDialog is not thread-safe.

XOPOpenFileDialog2

```
int
XOPOpenFileDialog2(flagsIn, prompt, fileFilterStr, fileFilterIndexPtr,
                        initialDir, initialFile, flagsOutPtr, fullPathOut)
int flagsIn;                        // Currently unused - must be 0
const char* prompt;                 // Prompt displayed in dialog
const char* fileFilterStr;
int* fileFilterIndexPtr;            // May be NULL
const char* initialDir;             // Full native path
const char* initialFile;
char fullPathOut[MAX_PATH_LEN+1];   // Set to a full native path
```

Displays the Open File dialog.

XOPOpenFileDialog2 returns 0 if the user chooses a file, or -1 if the user cancels, or another non-zero number in the event of an error.

It returns the full path to the chosen file via fullPathOut. This is a native path, using colons on Macintosh, backslashes on Windows.

In the event of a cancel, fullPathOut is unmodified.

flagsIn is currently unused. Pass 0 for this parameter.

prompt sets the dialog window title.

fileFilterStr controls the filters in the file filter popup menu that appears in the Open File dialog. The construction of this string is the same as documented in the Igor help for the Open operation /F flag. For example, this populate the filter popup menu with three filters:

```
const char* fileFilters = "Data Files (*.txt,*.dat,*.csv):.txt,.dat,.csv;" \
                          "HTML Files (*.htm,*.html):.htm,.html;" \
                          "All Files:.*;";
```

fileFilterIndexPtr is ignored if it is NULL. If it is not NULL, then *fileFilterIndexPtr is the 1-based index of the file type filter to be initially selected. In the example given above, setting *fileFilterIndexPtr to 2 would select the "HTML Files" file filter on entry to the dialog. On exit from the dialog, *fileFilterIndexPtr is set to the 1-based index of the file filter string that the user last selected.

initialDir can be "" or it can point to a full native path to a directory, with or without the trailing path separator. It determines the directory that will be initially displayed in the Open File dialog. If "", the directory will be the last directory that was seen in the open or save file dialogs. initialDir is a native path using colons on Macintosh, backslashes on Windows.

initialFile can be "" or it can be the name to which the File Name edit control in the Save File dialog is to be initialized. initialFile works on Windows only because the Macintosh Open File dialog has no File Name edit control.

flagsOutPtr is currently unused. Pass NULL for this parameter.

XOPOpenFileDialog2 returns, via fullPathOut, the full path to the file that the user chose. If the user cancels, fullPathOut is unchanged. fullPathOut is a native path using colons on Macintosh, backslashes on Windows.

Thread Safety

XOPOpenFileDialog2 is not thread-safe.

XOPSaveFileDialog

```
int
XOPSaveFileDialog(prompt, fileFilterStr, fileIndexPtr, initDir,
                                          defaultExtensionStr, fullFilePath)
const char* prompt;                // Message displayed in dialog
const char* fileFilterStr;         // Controls types of files shown
int* fileIndexPtr;                 // Controls initial type of file shown
const char* initDir;               // Sets initial directory
const char* defaultExtensionStr;   // Default file extension or NULL
char fullFilePath[MAX_PATH_LEN+1]; // Output path returned here
```

XOPSaveFileDialog is obsolescent. Use **XOPSaveFileDialog2** instead of XOPSaveFileDialog.

Displays the save file dialog.

XOPSaveFileDialog returns 0 if the user provides a file name or -1 if the user cancels or another non-zero number in the event of an error.

XOPSaveFileDialog returns the full path to the file via fullFilePath. fullFilePath is both an input and an output as explained below. In the event of a cancel, fullFilePath is unmodified.

fullFilePath is a native path (using colons on Macintosh, backslashes on Windows).

prompt sets the dialog window title.

fileFilterStr on Macintosh

If there is only one format in which you can save the file, pass "" for fileFilterStr. This will cause the Format menu to be hidden. If you can save the file in more than one format, pass a string like this:

```
"Plain Text:TEXT:.txt;Igor Text:IGTX:.itx;"
```

This would give you a Format menu like this:

```
Plain Text
Igor Text
```

fileFilterStr consists of sections terminated by a semicolon. For example, here is one section:

```
"Data Files:TEXT:.dat;"
```

Each section consists of three components: a menu item string (e.g., Data Files) to be displayed in the Format popup menu, a Macintosh file type (e.g., TEXT), and an extension (e.g., .dat).

At present, only the menu item string and extension are used.

The Macintosh file type is currently not used. If there is no meaningful Macintosh file type, leave the file type component empty.

If there is no meaningful extension, leave the extension component empty.

The Format popup menu in the Save File dialog allows the user to tell you in what format the file should be saved. Unlike the Enable popup menu in the Open File dialog, the Format menu has no filtering function. You find out which item the user chose via the fileIndexPtr parameter.

The syntax of the fileFilterStr is unforgiving. You must not use any extraneous spaces or any other extraneous characters. You must include the colons and semicolons as shown above. The trailing semicolon is required. If there is a syntax error, the entire fileFilterStr will be treated as if it were empty and you will get no Format menu.

fileFilterStr on Windows

On Windows, fileFilterStr identifies the types of files to display and the types of files that can be created. It is constructed as for the lpstrFilter field of the OPENFILENAME structure for the Windows GetSaveFileName routine. For example, to allow the user to save as a text file or as an Igor Text file, use:

```
"Text Files (*.txt)\0*.txt\0Igor Text Files (*.itx)\0*.itx\0\0"
```

Note that the string ends with two null characters (\0\0). If fileFilterStr is "", this behaves the same as "Text Files (*.txt)\0*.txt\0\0".

fileIndexPtr is ignored if it is NULL. If it is not NULL, then *fileIndexPtr is the one-based index of the file type filter to be initially selected. In the example given above, setting *fileIndexPtr to 2 would select the Igor Text file type on entry to the dialog. On exit from the dialog, *fileIndexPtr is set to the index of the file type string that the user last selected.

initialDir can be "" or it can point to a full path to a directory. It determines the directory that will be initially displayed in the save file dialog. If it is "", the directory will be the last directory that was seen in the Open File or Save File dialogs. If initialDir points to a valid path to a directory, then this directory will be initially displayed in the dialog. initialDir is a native path (using colons on Macintosh, backslashes on Windows).

defaultExtensionStr points to the extension to be added to the file name if the user does not enter an extension. For example, pass "txt" to have ".txt" appended if the user does not enter an extension. If you don't want any extension to be added in this case, pass NULL. Prior to XOP Toolkit 6, defaultExtensionStr was ignored on Macintosh.

XOPSaveFileDialog returns via fullFilePath the full path to the file that the user chose or "" if the user cancelled. The path is a native path (using colons on Macintosh, backslashes on Windows). fullFilePath must point to a buffer of at least MAX_PATH_LEN+1 bytes.

On both Windows and Macintosh, the initial value of fullFilePath sets the initial contents of the File Name edit control in the save file dialog. The following values are valid:

```
""
A file name
A full Macintosh or Windows path to a file
```

In the event of an error other than a cancel, XOPSaveFileDialog displays an error dialog. This should never or rarely happen.

Thread Safety

XOPSaveFileDialog is not thread-safe.

XOPSaveFileDialog2

```
int
XOPSaveFileDialog2(flagsIn, prompt, fileFilterStr, fileFilterIndexPtr,
                        initialDir, initialFile, flagsOutPtr, fullPathOut)
int flagsIn;                        // Currently unused - must be 0
const char* prompt;                 // Prompt displayed in dialog
const char* fileFilterStr;
int* fileFilterIndexPtr;            // May be NULL
const char* initialDir;             // Full native path
const char* initialFile;
char fullPathOut[MAX_PATH_LEN+1];   // Set to a full native path
```

Displays the Save File dialog.

XOPSaveFileDialog2 returns 0 if the user chooses a file, or -1 if the user cancels, or another non-zero number in the event of an error.

flagsIn is currently unused. Pass 0 for this parameter.

prompt sets the dialog window title.

fileFilterStr controls the filters in the file filter popup menu that appears in the Save File dialog. The construction of this string is the same as documented in the Igor help for the Open operation /F flag. For example, this populate the filter popup menu with three filters:

```
const char* fileFilters = "Data Files (*.txt,*.dat,*.csv):.txt,.dat,.csv;" \
                          "HTML Files (*.htm,*.html):.htm,.html;" \
                          "All Files:.*;";
```

fileFilterIndexPtr is ignored if it is NULL. If it is not NULL, then *fileFilterIndexPtr is the 1-based index of the file type filter to be initially selected. In the example given above, setting *fileFilterIndexPtr to 2 would select the "HTML Files" file filter on entry to the dialog. On exit from the dialog, *fileFilterIndexPtr is set to the 1-based index of the file filter string that the user last selected.

initialDir can be "" or it can point to a full native path to a directory, with or without the trailing path separator. It determines the directory that will be initially displayed in the Save File dialog. If "", the directory will be the last directory that was seen in the Open File or Save File dialogs. initialDir is a native path using colons on Macintosh, backslashes on Windows.

initialFile can be "" or it can be the name to which the File Name edit control in the Save File dialog is to be initialized.

flagsOutPtr is currently unused. Pass NULL for this parameter.

XOPSaveFileDialog2 returns, via fullPathOut, the full path to the file that the user chose. fullPathOut is a native path using colons on Macintosh, backslashes on Windows.

Thread Safety

XOPSaveFileDialog2 is not thread-safe.

Routines for File-Loader XOPs

These routines are specialized for file-loader XOPs — XOPs that load data from files into Igor waves.

GetFullPathFromSymbolicPathAndFilePath

```
int
GetFullPathFromSymbolicPathAndFilePath(pathName,filePath,fullFilePath)
const char* pathName;               // Igor symbolic path name
char filePath[MAX_PATH_LEN+1];      // Path to file
char fullFilePath[MAX_PATH_LEN+1];  // Output full path
```

pathName is the name of an Igor symbolic path or "" if no symbolic path is to be used.

filePath is either a full path, a partial path, or a simple file name. It may be a Macintosh HFS path (using colons) or a Windows path (using backslashes).

fullFilePath is an output and will contain the full native path (using colons on Macintosh, backslashes on Windows) to the file referenced by the symbolic path and the file path. It must be big enough to hold MAX_PATH_LEN+1 bytes.

This routine is used by file loader XOPs to get a full native path to a file based on the typical inputs to a file loader, namely an optional Igor symbolic path and an optional full or partial file path or file name.

The three most common cases are:

```
LoadWave <full path to file>
LoadWave/P=<symbolic path name> <partial path to file>
LoadWave/P=<symbolic path name> <file name>
```

where <file name> connotes a simple file name.

In this case GetFullPathFromSymbolicPathAndFilePath ignores the symbolic path:

```
LoadWave/P=<symbolic path name> <full path to file>
```

In the following cases, the full path to the file can not be determined, so GetFullPathFromSymbolic-PathAndFilePath returns an error. This would cause a file loader to display an open file dialog:

```
LoadWave <file name>
LoadWave <partial path to file>
```

filePath and fullFilePath may point to the same storage, in which case the output string will overwrite the input string.

This routine does not check that the output path is valid or points to an existing file. This makes the routine useable for applications in which you are creating the file as well as applications in which you are reading the file. If you want to verify that the output path points to an existing file, use the **FullPathPointsToFile** routine.

The function result is 0 if it was able to create the full path or an error code if not.

Thread Safety

GetFullPathFromSymbolicPathAndFilePath is not thread-safe because it calls **GetPathInfo2** which is not thread-safe.

FileLoaderMakeWave

```
int
FileLoaderMakeWave(column, waveName, numPoints, fileLoaderFlags, whp)
int column;               // Number of column for this wave
char* waveName;           // Name for this wave
CountInt numPoints;       // Number of points in wave
int fileLoaderFlags;      // Standard file-loader flags
waveHndl* waveHPtr;       // Place to store handle for new wave
```

This routine is intended for use in simple file-loader XOPs such as SimpleLoadWave. It makes a wave with numPoints points and with the numeric type as specified by fileLoaderFlags.

The function result is 0 or an error code.

It returns a handle to the wave via waveHPtr or NULL in the event of an error.

fileLoaderFlags is interpreted using the standard file-loader flag bit definitions in XOP.h.

If (fileLoaderFlags & FILE_LOADER_OVERWRITE) is non-zero, FileLoaderMakeWaves overwrites any pre-existing wave in the current data folder with the specified name.

If (fileLoaderFlags & FILE_LOADER_DOUBLE_PRECISION) is non-zero, FileLoaderMakeWaves creates a double-precision floating point wave. Otherwise, it creates a single-precision floating point wave.

If (fileLoaderFlags & FILE_LOADER_COMPLEX) is non-zero, FileLoaderMakeWaves creates a complex wave. Otherwise, it creates a real point wave.

column should be the number of the column being loaded or the number of the wave in a set of waves or zero if this does not apply to your XOP.

NOTE: In the event of a name conflict, FileLoaderMakeWave will change the contents of waveName. waveName must be big enough to hold MAX_OBJ_NAME+1 bytes.

Prior to XOP Toolkit 6, if the numPoints parameter was zero, the wave was created with 128 points. This behavior was a relic of a time when Igor required that a wave contain at least two points (prior to Igor Pro 3.0). Now when numPoints is zero, a zero-point wave is created.

If you find that you need more flexibility, use **MakeWave**, **MDMakeWave** or **GetOperationDestWave** instead of FileLoaderMakeWave.

Thread Safety

FileLoaderMakeWave is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

SetFileLoaderOutputVariables

```
int
SetFileLoaderOutputVariables(fileNameOrPath, numWavesLoaded, waveNames)
char* fileNameOrPath;     // Name of or full path to the file just loaded
int numWavesLoaded;       // Number of waves loaded
char* waveNames;          // Semicolon-separated list of wave names
```

If your external operation uses Operation Handler, use **SetFileLoaderOperationOutputVariables** instead of this routine.

Call SetFileLoaderOutputVariables at the end of a file load operation to set the standard file loader output globals:

Variable	Contents
S_fileName	The name of the file loaded
S_path	The full path to the folder containing the file (see description below)

Variable	Contents
V_flag	The number of waves loaded
S_waveNames	Semicolon-separate list of wave names (e.g. "wave0;wave1;")

fileNameOrPath can be either just the file name (e.g., "Data File") or a full path including a file name (e.g., "hd:Data Folder:Data File"). Passing a full path is recommended. If it is a full path, it can be a Macintosh HFS path (using colons) or a Windows path (using backslashes).

If fileNameOrPath is a full path, SetFileLoaderOutputVariables stores the path to the folder containing the file in S_path and stores the simple file name in S_fileName. In this case, the stored path uses Macintosh HFS path syntax and includes a trailing colon.

If fileNameOrPath is a simple file name, SetFileLoaderOutputVariables does not set or create S_path and stores the simple file name in S_fileName. You should pass a full path so that S_path will be set.

SetFileLoaderOutputVariables returns 0 or an error code.

Thread Safety

SetFileLoaderOutputVariables is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

SetFileLoaderOperationOutputVariables

```
int
SetFileLoaderOperationOutputVariables(runningInUserFunction, fileNameOrPath,
                                             numWavesLoaded, waveNames)
int runningInUserFunction; // Truth that operation was called from function
const char* fileNameOrPath;// Name of or full path to the file just loaded
int numWavesLoaded;        // Number of waves created
const char* waveNames;     // Semicolon-separated list of wave names
```

Call SetFileLoaderOperationOutputVariables at the end of an Operation Handler file load operation to set the standard file loader output globals.

When called from the command line it creates global variables.

When called from a user-defined function or from a macro it creates local variables.

You obtain the value to pass for the runningInUserFunction parameter from the calledFromFunction field of your operation's runtime parameter structure.

When you register your operation via **RegisterOperation**, you must specify that your operation sets the numeric variable V_flag and the string variables S_fileName, S_path, and S_waveNames. See SimpleLoad-WaveOperation.cpp for an example.

SetFileLoaderOperationOutputVariables sets the following standard file loader output globals:

Variable	Contents
S_fileName	The name of the file loaded.
S_path	The full path to the folder containing the file. See description below.
V_flag	The number of waves loaded.
S_waveNames	Semicolon-separate list of wave names (e.g. "wave0;wave1;").

fileNameOrPath can be either just the file name (e.g., "Data File") or a full path including a file name (e.g., "hd:Data Folder:Data File"). Passing a full path is recommended. If it is a full path, it can be a Macintosh HFS path (using colons) or a Windows path (using backslashes).

If fileNameOrPath is a full path, SetFileLoaderOperationOutputVariables stores the path to the folder containing the file in S_path and stores the simple file name in S_fileName. In this case, the stored path uses Macintosh HFS path syntax and includes a trailing colon.

If fileNameOrPath is a simple file name, SetFileLoaderOperationOutputVariables does not set S_path and stores the simple file name in S_fileName. You should pass a full path so that S_path will be set.

SetFileLoaderOperationOutputVariables returns 0 or error code.

Thread Safety

SetFileLoaderOperationOutputVariables is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

Routines for XOPs with Windows

Documentation for routines supporting XOP windows can be found in the following XOPSupport files:

XOPWindows.c

XOPContainers.c

See Chapter 9, **Adding Windows**, for further information.

Routines for XOPs with Text Windows

Igor provides a group of routines, called TU ("Text Utility") routines, that allow an XOP to implement a fully functional text window, like Igor's built-in procedure window. Documentation for routines supporting text windows can be found in the following XOPSupport file:

XOPTextUtilityWindows.c

Routines for Dealing with Resources

These callbacks are useful for accessing resources from within an XOP. Most XOPs will not need to deal directly with resources and so will not need to use these routines.

XOPRefNum

```
int
XOPRefNum(void)
```

This routine is supported on Macintosh only. There is no Windows equivalent.

Returns the file reference number for the XOP's own resource fork.

Thread Safety

XOPRefNum is thread-safe but there is little if anything you can do with the returned reference number that is thread-safe.

GetXOPResource

```
Handle
GetXOPResource(resType, resID)
int resType;               // Resource type, e.g., 'DLOG'
int resID;                 // Resource ID number
```

This routine is supported on Macintosh only. There is no Windows equivalent.

GetXOPResource returns a Mac OS handle to the specified resource in the XOP's resource fork or NULL if there is no such resource.

This routine does not search any other resource forks.

Mac OS handles can not be passed to WaveMetrics routines such as WMGetHandleSize and WMDispose-Handle. You must use Mac OS routines for this purpose. See **Updating Old Code to Use WM Memory XOPSupport Routines** on page 182 for details.

Thread Safety

GetXOPResource is not thread-safe.

GetXOPNamedResource

```
Handle
GetXOPNamedResource(resType, name)
int resType;               // Resource type, e.g., 'DLOG'
char* name;                // C string containing resource name
```

This routine is supported on Macintosh only. There is no Windows equivalent.

GetXOPNamedResource returns a Mac OS handle to the specified resource in the XOP's resource fork or NULL if there is no such resource.

This routine does not search any other resource forks.

Mac OS handles can not be passed to WaveMetrics routines such as WMGetHandleSize and WMDispose-Handle. You must use Mac OS routines for this purpose. See **Updating Old Code to Use WM Memory XOPSupport Routines** on page 182 for details.

Thread Safety

GetXOPNamedResource is not thread-safe.

GetXOPIndString

```
void
GetXOPIndString(text, strID, item)
char* text;             // C string to hold up to 256 characters
int strID;              // ID of STR# resource in XOP's resource fork
int item;               // String number within resource starting from one
```

Returns the specified string from the specified STR# resource in the XOP’s resource fork via the text parameter. This routine does not search any other resource forks.

This routine can be used on both Macintosh and Windows.

Thread Safety

GetXOPIndString is not thread-safe.

Routines for XOPs That Use FIFOs

Igor Pro provides First-In-First-Out (FIFO) objects for use in data acquisition tasks where a continuous stream of data is generated and where you want to monitor the data in real-time with a visual chart recorder-like display. If you have a continuous stream of data but you don’t want to use a chart display to monitor it, then you can do your own thing and you do not need to involve FIFOs.

There are two ways to get acquired data from an XOP into a FIFO.

If the data rate is slow, say less than 10 values/second, then you could set up an Igor Pro background task to call your XOP to get data. In this case your XOP does not need to use the FIFO routines. There are problems associated with this technique but it is *much* easier than directly writing into FIFOs. See the Igor Pro manual for a discussion of background tasks.

If the data is coming in quickly, then you will need to directly write data into an Igor Pro FIFO object. You can get a feel for the FIFO technique by examining the Sound Chart Demo example experiment ("Igor Pro Folder:Examples:Movies & Audio:Sound Input").

To use the FIFO technique, you will need to set up an idle routine in your XOP that gets the handle to a given FIFO object, writes data to it and then notifies Igor Pro of that fact. Since idle routines are only called when Igor Pro “gets a chance”, you will have to define your own buffer to store data until the next time your idle routine is called. Under some conditions, it can be many seconds between idle calls. Your buffer has to be large enough to handle this amount of data.

There is additional documentation for FIFOs in the Igor Pro help; see the “FIFOs and Charts” help topic. XOP support for FIFOs consists of the following routines plus the NamedFIFO.h file in the XOPSupport folder.

GetNamedFIFO

```
struct NamedFIFO **
GetNamedFIFO(name)
char name[MAX_OBJ_NAME+1]; // C string to receive name
```

Returns the named FIFO handle or NULL if none of that name exists.

FIFO handles belong to Igor so you should not dispose them.

Thread Safety

GetNamedFIFO is not thread-safe.

MarkFIFOUpdated

```
void
MarkFIFOUpdated(fifo)
struct NamedFIFO **fifo;   // Handle to an existing FIFO
```

Tells Igor Pro that you have modified the data in a FIFO.

Call this after putting data in a named FIFO so that Igor Pro will refresh chart gadgets.

Thread Safety

MarkFIFOUpdated is not thread-safe.

Numeric Conversion Routines

These XOPSupport routines convert between various numeric formats and are useful for importing or exporting data as well as for other purposes. They are defined in the file XOPNumericConversion.c.

Some of the routines take a pointer to some input data and a pointer to a place to put the converted output data. Numbers can be converted in place. That is, the pointer to the input data and the pointer to the output data can point to the same array in memory. Make sure that the array is big enough to hold the data in the output format.

These routines are used in the GBLoadWaveX, VDT2 and NIGPIB2 sample XOPs.

XOP Toolkit routines use two different ways to specify a number type:

- XOP Toolkit number format code plus a count of bytes per number.
- Igor number type code.

This table shows how these two methods relate:

Number Type	XOP Toolkit Code/Count	Igor Code
Double-precision floating point	IEEE_FLOAT, 8	NT_FP64
Single-precision floating point	IEEE_FLOAT, 4	NT_FP32
SInt64 (64 bits)	SIGNED_INT, 8	NT_I64
SInt32 (32 bits)	SIGNED_INT, 4	NT_I32
Short integer (16 bits)	SIGNED_INT, 2	NT_I16
Byte integer (8 bits)	SIGNED_INT, 1	NT_I8
UInt64 (64 bits)	UNSIGNED_INT, 8	NT_I64 | NT_UNSIGNED
UInt32 (32 bits)	UNSIGNED_INT, 4	NT_I32 | NT_UNSIGNED
Unsigned short integer (16 bits)	UNSIGNED_INT, 2	NT_I16 | NT_UNSIGNED
Unsigned byte integer (8 bits)	UNSIGNED_INT, 1	NT_I8 | NT_UNSIGNED

Originally, Igor supported only single-precision (NT_FP32) and double-precision (NT_FP64) floating point. Thus, to describe other types, the XOP Toolkit codes were invented.

ConvertData

```
int
ConvertData(src,dest,numValues,srcBytes,srcFormat,destBytes,destFormat)
void* src;              // Input data in format specified by srcFormat
void* dest;             // Output data in format specified by destFormat
CountInt numValues;     // Number of values to convert
int srcBytes;           // Number of bytes in a point of input (1, 2, 4, or 8)
int srcFormat;          // XOP Toolkit code for input data format
int destBytes;          // Number of bytes in a point of output (1, 2, 4, or 8)
int destFormat;         // XOP Toolkit code for output data format
```

This routine calls the appropriate conversion routine based on the srcBytes, srcFormat, destBytes and dest-Format parameters.

ConvertData can handle any combination of the legal Igor numeric data types. It takes the description of source and destination data types in the form of an XOP Toolkit numeric format code, defined in XOPSup-port.h, and a number of bytes. Both the source and destination can be any of the following:

```
format = IEEE_FLOAT, numBytes = 8   // Double-precision IEEE float
format = IEEE_FLOAT, numBytes = 4   // Single-precision IEEE float
format = SIGNED_INT, numBytes = 8   // 64 bit signed integer
format = SIGNED_INT, numBytes = 4   // 32 bit signed integer
format = SIGNED_INT, numBytes = 2   // 16 bit signed integer
format = SIGNED_INT, numBytes = 1   // 8 bit signed integer
format = UNSIGNED_INT, numBytes = 8 // 64 bit unsigned integer
format = UNSIGNED_INT, numBytes = 4 // 32 bit unsigned integer
format = UNSIGNED_INT, numBytes = 2 // 16 bit unsigned integer
format = UNSIGNED_INT, numBytes = 1 // 8 bit unsigned integer
```

Returns zero if everything is OK, 1 if the conversion is not supported (e.g., converting to 2 byte floating point), -1 if no conversion is needed (source format == dest format).

ConvertData relies on a large number of low-level conversion routines with names of the form <Source Type>To<Dest Type> where both <Source Type> and <Dest Type> can be any of the following:

Double, Float, SInt64, SInt32, Short, Byte, UInt64, UInt32, UnsignedShort, UnsignedByte

For most uses, you should use the higher level ConvertData routine.

Thread Safety

ConvertData is thread-safe. It can be called from any thread.

ConvertData2

```
int
ConvertData2(src, dest, numValues, srcDataType, destDataType)
void* src;              // Input data in format specified by srcDataType
void* dest;             // Output data in format specified by destDataType
CountInt numValues;     // # of values to convert
int srcDataType;        // Igor code for input data format
int destDataType;       // Igor code for output data format
```

This routine calls the appropriate conversion routine based on the srcDataType and destDataType parameters.

ConvertData2 can handle any combination of the legal Igor numeric data types. It takes the description of source and destination data types in the form Igor number type codes, defined in IgorXOP.h. Both the srcDataType and destDataType can be any of the following:

```
NT_FP64                 // Double-precision IEEE float
NT_FP32                 // Single-precision IEEE float
NT_I64                  // 64 bit signed integer
NT_I32                  // 32 bit signed integer
NT_I16                  // 16 bit signed integer
NT_I8                   // 8 bit signed integer
NT_I64 | NT_UNSIGNED    // 64 bit unsigned integer
NT_I32 | NT_UNSIGNED    // 32 bit unsigned integer
NT_I16 | NT_UNSIGNED    // 16 bit unsigned integer
NT_I8 | NT_UNSIGNED     // 8 bit unsigned integer
```

The number type should *not* include NT_CMPLX. If the data is complex, the numValues parameter should reflect that.

Returns zero if everything is OK, 1 if the conversion is not supported (e.g., converting to 2 byte floating point), -1 if no conversion is needed (source format == dest format).

Thread Safety

ConvertData2 is thread-safe. It can be called from any thread.

NumTypeToNumBytesAndFormat

```
int
NumTypeToNumBytesAndFormat(numType, numBytesPerValuePtr, dataFormatPtr,
isComplexPtr)
int numType;                // Igor number type code.
int* numBytesPerValuePtr;   // Output: number of bytes per value.
int* dataFormatPtr;         // Output: XOP Toolkit data format code.
int* isComplexPtr;          // Output: True if complex.
```

This routine converts standard Igor number type codes (e.g., NT_FP64), which are defined in IgorXOP.h, into the XOP Toolkit number format codes (IEEE_FLOAT, SIGNED_INT, and UNSIGNED_INT), defined in XOPSupport.h.

The value returned via numBytesPerValuePtr is the number of bytes per value, not the number of bytes per point. In other words, if a point of a wave is complex, it will take twice as many bytes as returned via numBytesPerValuePtr .

Thread Safety

NumTypeToNumBytesAndFormat is thread-safe. It can be called from any thread.

NumBytesAndFormatToNumType

```
int
NumBytesAndFormatToNumType(numBytesPerValue, dataFormat, numTypePtr)
int numBytesPerValue;       // Number of bytes per value.
int dataFormat;             // XOP Toolkit data format code.
int* numTypePtr;            // Output: Igor number type code.
```

This routine is converts XOP Toolkit data format codes (IEEE_FLOAT, SIGNED_INT, and UNSIGNED_INT), defined in XOPSupport.h, into standard Igor number type codes (e.g., NT_FP64), defined in IgorXOP.h.

Thread Safety

NumBytesAndFormatToNumType is thread-safe. It can be called from any thread.

ScaleData

```
void
ScaleData(dataType, dataPtr, offsetPtr, multiplierPtr, numValues)
int dataType;               // Code for input data format
void* dataPtr;              // Pointer to data to be scaled
double* offsetPtr;          // Pointer to the offset value
double* multiplierPtr;      // Pointer to the multiplier value
CountInt numValues;         // Code for output data format
```

Scales the data pointed to by dataPtr by adding the offset and multiplying by the multiplier.

dataType is one of the Igor numeric type codes defined in IgorXOP.h (same as for **ConvertData2**).

The NT_CMPLX bit must *not* be set. If the data is complex, this must be reflected in the numValues parameter.

All calculations are done in double precision.

Scaling of signed and unsigned 64-bit integer values is subject to inaccuracies for values exceeding 2^53 in magnitude because calculations are done in double-precision and double-precision can not precisely represent the full range of 64-integer values. In evaluating the result, if any value exceeds 2^53 in magnitude, the result is undefined. See **64-bit Integer Issues** on page 204 for further discussion.

Thread Safety

ScaleData is thread-safe. It can be called from any thread.

ScaleClipAndRoundData

```
void
ScaleClipAndRoundData(dataType, dataPtr, numValues, offset, multiplier, dMin,
dMax, doRound)
int dataType;              // Code for input data format
void* dataPtr;             // Pointer to data to be scaled
CountInt numValues;        // Code for output data format
double offset;             // Offset value
double multiplier;         // Multiplier value
double dMin;               // Min value for clipping
double dMax;               // Max value for clipping
int doRound;               // If non-zero, rounding is performed
```

Scales the data pointed to by dataPtr by adding the offset and multiplying by the multiplier. If offset is 0.0 and multiplier is 1.0, no scaling is done.

Clips to the specified min and max. If min is -INF and max is +INF, no clipping is done.

If min and max are both zero, integer data is clipped to the minimum and maximum values that can be represented by the data type except for signed and unsigned 64-bit integer. The largest integer value that can be precisely represented in double-precision floating point is 2^53 = 9007199254740992. For signed 64-bit integer (NT_I64), the minimum is -9007199254740992 and the maximum is 9007199254740992. For unsigned 64-bit integer (NT_I64 | NT_UNSIGNED), the minimum is 0 and the maximum is 9007199254740992.

If doRound is non-zero, the data is rounded to the nearest integer.

All calculations are done in double precision.

Scaling of signed and unsigned 64-bit integer values is subject to inaccuracies for values exceeding 2^53 in magnitude because calculations are done in double-precision and double-precision can not precisely represent the full range of 64-integer values. In evaluating the result, if any value exceeds 2^53 in magnitude, the result is undefined. See **64-bit Integer Issues** on page 204 for further discussion.

dataType is one of the Igor numeric type codes defined in IgorXOP.h (same as for **ConvertData2**).

The NT_CMPLX bit must *not* be set. If the data is complex, this must be reflected in the numValues parameter.

Thread Safety

ScaleClipAndRoundData is thread-safe. It can be called from any thread.

FixByteOrder

```
void
FixByteOrder(p, bytesPerPoint, numValues)
void* p;                   // Pointer to input data of any type
int bytesPerPoint;         // Bytes in one point of input format
CountInt numValues;        // Number of values to fix
```

The routine converts data from Motorola (high byte first) to Intel (low byte first) format or vice-versa.

Thread Safety

FixByteOrder is thread-safe. It can be called from any thread.

Routines for Dealing With Object Names

If your XOP creates a new data object (a wave, variable or data folder) you need to provide a legal name. The name must also be unique, unless you are overwriting an existing object. The **CreateValidDataObject-Name** routine, described below, is appropriate for most uses and does all necessary legality and conflict checking.

If you pass a string to Igor for execution as a command, using **XOPCommand**, **XOPCommand2**, **XOPCommand3**, **XOPSilentCommand** or **FinishDialogCmd** you must quote liberal object names. Use **PossiblyQuoteName** and **CatPossiblyQuotedName** for this purpose. See the Igor Pro manual for general information on liberal names.

UniqueName

```
int
UniqueName(baseName, finalName)
const char* baseName;           // C string containing base name
char finalName[MAX_OBJ_NAME+1]; // C string containing new, unique name
```

New XOPs should use **CreateValidDataObjectName** or **UniqueName2** instead of UniqueName.

UniqueName generates a name that does not conflict with an existing name.

This is used by operations that want to create waves and auto-name them (like LoadWaves/A).

The finalName is derived by appending one or more digits to the baseName. finalName must be able to hold MAX_OBJ_NAME+1 bytes.

Make sure that the baseName is not too long. Otherwise, the finalName could be too long to be a legal name.

The function result is the number that was appended to the baseName to make the finalName.

Thread Safety

UniqueName is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

UniqueName2

```
int
UniqueName2(nameSpaceCode, baseName, finalName, suffixNumPtr)
int nameSpaceCode;              // Usually MAIN_NAME_SPACE. See IgorXOP.h
const char* baseName;           // Base name to use for creating unique name
char finalName[MAX_OBJ_NAME+1]; // Receives unique name
int suffixNumPtr;               // Keeps track of last suffix used
```

If your goal is to generate a valid object name that you can use to create a data object, consider using **Cre-ateValidDataObjectName** instead of this routine.

UniqueName2 generates a name that does not conflict with an existing name.

The function result is 0 if OK, -1 for a bad nameSpaceCode or some other error code.

This is an improved version of **UniqueName**. Given a base name (like "wave") UniqueName2 returns a name (like "wave3") via finalName that does not conflict with any existing names. finalName must be able to hold MAX_OBJ_NAME+1 bytes.

*suffixNumPtr is both an input and an output. Its purpose is to speed up the search for unique names when creating a batch of names in a loop. The number appended to make the name unique will be *suffix-NumPtr or greater. Igor sets *suffixNumPtr to the number Igor used to make the name unique. Typically, you should set *suffixNumPtr to zero before your first call to UniqueName2.

nameSpaceCode is MAIN_NAME_SPACE for Igor’s main name space (waves, variables, windows).

nameSpaceCode is DATA_FOLDER_NAME_SPACE for data folders.

See IgorXOP.h for other less frequently-used name space codes.

Thread Safety

UniqueName2 is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

UniqueName2 returns an error if called from an Igor pre-emptive thread if namespaceCode is other than MAIN_NAME_SPACE, DATAFOLDERS_NAME_SPACE, or PATHS_NAME_SPACE.

SanitizeWaveName

```
int
SanitizeWaveName(waveName, column)
char waveName[MAX_OBJ_NAME+1];    // Input and output wave name
int column;                       // Number of column being loaded or zero
```

This routine is obsolete. Use **CleanupName**, **CheckName** and **CreateValidDataObjectName** instead of SanitizeWaveName.

SanitizeWaveName is intended mainly for use in file-loader XOPs such as SimpleLoadWave but may have other uses.

Given a pointer to a C string containing a proposed wave name, SanitizeWaveName changes it to make it a valid wave name if necessary. It returns 1 if it had to make a change, 0 if name was OK to begin with. waveName must be able to hold MAX_OBJ_NAME+1 bytes.

First SanitizeWaveName truncates the proposed name if it is too long. Then it makes sure that the first character is alphabetic. Then it replaces any subsequent characters that are not alphanumeric with underscore.

column should be the number of the column being loaded or the number of the wave in a set of waves or zero if this does not apply to your XOP.

Thread Safety

SanitizeWaveName is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

CleanupName

```
int
CleanupName(beLiberal, name, maxNameBytes)
int beLiberal;
char* name;
int maxNameBytes;
```

If your goal is to generate a valid object name that you can use to create a data object, consider using **CreateValidDataObjectName** instead of CleanupName.

CleanupName changes the name, if necessary, to make it a legal Igor object name.

On input, name may be longer than maxNameBytes bytes. On output, it is truncated if necessary.

For most uses, pass MAX_OBJ_NAME for the maxNameBytes parameter. name must be able to hold maxNameBytes+1 bytes.

Wave and data folder names can contain characters, such as space and dot. We call this “liberal” name rules.

If beLiberal is non-zero, CleanupName uses liberal name rules. Liberal rules are allowed for wave and data folder names but are not allowed for string and numeric variable names so pass zero for beLiberal for these objects.

If you are going to use the name in Igor's command line (via the Execute operation or via the XOPCommand or XOPSilentCommand callbacks), and if the name uses liberal rules, the name needs to be single-quoted. In these cases, you should call **PossiblyQuoteName** after calling CleanupName.

Thread Safety

CleanupName is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

CheckName

```
int
CheckName(dataFolderH, objectType, name)
DataFolderHandle dataFolderH;
int objectType;
char name[MAX_OBJ_NAME+1];
```

If your goal is to generate a valid object name that you can use to create a data object, consider using **CreateValidDataObjectName** instead of this routine.

CheckName checks the name for legality and uniqueness.

If dataFolderH is NULL, it looks for conflicts with objects in the current data folder. If it is not NULL, it looks for conflicts in the folder specified by dataFolderH.

objectType is one of the following (defined in IgorXOP.h):

`WAVE_OBJECT`	Threadsafe
`VAR_OBJECT (numeric variable)`	Threadsafe
`STR_OBJECT (string variable)`	Threadsafe
`DATAFOLDER_OBJECT`	Threadsafe
`PATH_OBJECT`	Threadsafe
`GRAPH_OBJECT`	Not threadsafe
`TABLE_OBJECT`	Not threadsafe
`LAYOUT_OBJECT`	Not threadsafe
`PANEL_OBJECT`	Not threadsafe
`NOTEBOOK_OBJECT`	Not threadsafe
`PICT_OBJECT`	Not threadsafe

The function result is 0 if the name is legal and is not in conflict with an existing object.

Returns an Igor error code otherwise.

Thread Safety

CheckName is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

CheckName returns an error if called from an Igor pre-emptive thread if objectType is other than WAVE_OBJECT, VAR_OBJECT, STR_OBJECT, DATAFOLDER_OBJECT, or PATH_OBJECT.

CreateValidDataObjectName

```
int
CreateValidDataObjectName(
DataFolderHandle dataFolderH, // Handle to data folder or NULL
const char* inName,           // Input: Proposed name
char outName[MAX_OBJ_NAME+1], // Output: Valid name
int* suffixNumPtr,            // Used to make name unique
int objectType,               // Type code from IgorXOP.h
int beLiberal,                // 1 to allow liberal names
int allowOverwrite,           // 1 if it is OK to overwrite object
int inNameIsBaseName,         // 1 if inName needs digits appended
int printMessage,             // 1 to print message about conflict
int* nameChangedPtr,          // Output: 1 if name changed
int* doOverwritePtr)          // Output: 1 if need to overwrite object
```

This routine is designed to do all of the nasty work needed to get a legal name for a given object. It cleans up illegal names and resolves name conflicts.

It returns in outName a name that can be safely used to create a data object of a given type (wave, string variable, numeric variable, data folder).

inName is the proposed name for the object or a base name to which one or more digits is to be added.

outName is the name after possible cleanup and uniquification. outName must be able to hold MAX_OBJ_NAME+1 bytes.

*suffixNumPtr is both an input and an output. Its purpose is to speed up the search for unique names when creating a batch of names in a loop. The number appended to make the name unique will be *suffixNumPtr or greater. Igor sets *suffixNumPtr to the number Igor used to make the name unique. Typically, you should set *suffixNumPtr to zero before your first call to CreateValidDataObjectName.

dataFolderH is a handle to a data folder or NULL to use the current data folder.

objectType is one of the following:

```
WAVE_OBJECT, VAR_OBJECT, STR_OBJECT, DATAFOLDER_OBJECT
```

beLiberal is 1 if you want to allow liberal names or 0 if not. If the object type is VAR_OBJECT or STR_OBJECT, the name will not be liberal, even if beLiberal is 1. Igor allows only wave and data folder names to be liberal.

allowOverwrite is 1 if it is OK for outName to be the name of an existing object of the same type.

inNameIsBaseName should be 1 if inName is a base name (e.g., "wave") to which a suffix (e.g., "0") must always be added to produce the actual name (e.g., "wave0"). If inNameIsBaseName is 0 then no suffix will be added to inName unless it is needed to make the name unique.

printMessage is 1 if you want CreateValidDataObjectName to print a message in Igor's history area if an unexpected name conflict occurs. A message is printed if you are not using a base name and not allowing overwriting and there is a name conflict. A message is also printed if a conflict with an object of a different type prevents the normal name from being used.

CreateValidDataObjectName sets *nameChangedPtr to the truth that outName is different from inName.

It sets *doOverwritePtr to the truth that outName is the name of an existing object of the same type and allowOverwrite is 1.

inName and outName can point to the same array if you don't want to preserve the original name. Both must be big enough to hold MAX_OBJ_NAME+1 bytes.

The function result is 0 if OK or an error code.

Example

This is a simplified section of code from GBLoadWaveX which uses CreateValidDataObjectName. lpp is a pointer to a structure containing parameters for the load operation. ciHandle is a locked handle containing an array of records, one for each wave to be created.

```
IndexInt column;
int suffixNum;
char base[MAX_OBJ_NAME+1];
int nameChanged, doOverwrite;
int result;

strcpy(base, "wave");      // Base name for waves.
suffixNum = 0;
for (column = 0; column < lpp->numArrays; column++) {
   ciPtr = *ciHandle + column;
   ciPtr->points = lpp->arrayPoints;
   strcpy(ciPtr->waveName, base);

   // Take care of illegal or conflicting names.
   result = CreateValidDataObjectName(NULL, ciPtr->waveName,
               ciPtr->waveName, &suffixNum, WAVE_OBJECT, 1,
               lpp->flags & OVERWRITE, 1, 1, &nameChanged, &doOverwrite);

   ciPtr->wavePreExisted = doOverwrite;

   if (result == 0)
      result = MakeAWave(ciPtr->waveName, lpp->flags, &ciPtr->waveHandle,
                         lpp->arrayPoints, lpp->outputDataType);

   if (result) {            // Couldn't make wave (probably low memory) ?
      <Clean up>;
      return result;
   }
}
```

Thread Safety

CreateValidDataObjectName is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

PossiblyQuoteName

```
int
PossiblyQuoteName(name)
char name[MAX_OBJ_NAME+2+1];
```

PossiblyQuoteName puts single quotes around the Igor object name if they would be needed to use the name in Igor's command line.

A wave or data folder name can be either a "standard" name or a "liberal" name. Standard names start with a letter and contain letters, digits and underscore characters only. Liberal names can contain spaces and punctuation.

When a liberal name is used in Igor's command line it must be enclosed in single quotes. This includes using it in the Execute operation or in the **XOPCommand**, **XOPCommand2**, **XOPCommand3**, **XOPSilent-Command** or **FinishDialogCmd** XOPSupport routines. Thus, if you are going to use a wave or data folder name for this purpose, you should call PossiblyQuoteName to add the quotes if needed.

NOTE: name must be able to hold MAX_OBJ_NAME plus two additional bytes plus the null terminator. Thus you should declare name as shown above.

NOTE: Liberal rules are not allowed for string and numeric variable names.

PossiblyQuoteName returns 0 if the name is not liberal, 1 if it is liberal.

Thread Safety

PossiblyQuoteName is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

CatPossiblyQuotedName

```
int
CatPossiblyQuotedName(str, name)
char* str;
char name[MAX_OBJ_NAME+2+1];
```

Adds the specified Igor object name to the end of the string. If necessary, puts single quotes around the name so that it can be used in the Igor command line.

Use this to concatenate a wave name to the end of a command string when the wave name may be a liberal name that needs to be quoted to be used in the command line.

The memory pointed to by str must be big enough to hold an additional MAX_OBJ_NAME+2 bytes, plus the null terminator.

See **PossiblyQuoteName** for details on liberal names.

Remember that the quoted name will take an extra two bytes. str must be big enough to hold it.

CatPossiblyQuotedName returns 0 if the name is not liberal, 1 if it is liberal.

Example

```
char waveName[MAX_OBJ_NAME+1];    // This contains a wave name.
char cmd[MAX_OBJ_NAME+2+32+1];
strcpy(cmd, "Display ");
CatPossiblyQuotedName(cmd, waveName);
XOPSilentCommand(cmd);
```

Thread Safety

CatPossiblyQuotedName is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

Color Table Routines

These routines were added to the XOP Toolkit for use by advanced programmers who want to present a user interface with the same color tables as Igor itself presents.

GetIndexedIgorColorTableName

```
int
GetIndexedIgorColorTableName(index, name)
int index;                 // Zero-based index of a color table
char name[MAX_OBJ_NAME+1]; // Output: name of that color table
```

Returns via name the name of a color table indicated by the index or "" if the index is invalid.

Valid indices start from zero. You can find the maximum valid index by calling this routine with increasing indices until it returns an error.

The function result is 0 if OK or a non-zero error code if the index is invalid.

Thread Safety

GetIndexedIgorColorTableName is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

GetNamedIgorColorTableHandle

```
int
GetNamedIgorColorTableHandle(name, ictHPtr)
const char* name;                // Name of a color table
IgorColorTableHandle* ictHPtr;   // Handle to color table info
```

Returns via *ictHPtr a handle to an Igor color table or NULL in case of error.

The returned handle belongs to Igor. Do not modify or delete it.

The name parameter is case insensitive.

You can find the names of all color tables using **GetIndexedIgorColorTableName**.

The function result is 0 if OK or a non-zero error code.

Thread Safety

GetNamedIgorColorTableHandle is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

GetIgorColorTableInfo

```
int
GetIgorColorTableInfo(ictH, name, numColorsPtr)
IgorColorTableHandle ictH;    // Handle from GetNamedIgorColorTableHandle
char name[MAX_OBJ_NAME+1];    // Output: name of color table
int* numColorsPtr;            // Output: number of colors in table
```

Provides access to the name and the number of colors in the Igor color table specified by ictH.

ictH is a handle that you got by calling **GetNamedIgorColorTableHandle**.

If you don't want to know the name, pass NULL for name. If you don't want to know the number of colors, pass NULL for numColorsPtr.

The function result is 0 if OK or a non-zero error code.

Thread Safety

GetIgorColorTableInfo is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

GetIgorColorTableValues

```
int
GetIgorColorTableValues(ictH, startIndex, endIndex, updateVals, csPtr)
IgorColorTableHandle ictH; // Handle from GetNamedIgorColorTableHandle
int startIndex;            // Index of first color of interest
int endIndex;              // Index of last color of interest
int updateVals;
IgorColorSpec* csPtr;      // Output: Color values go here
```

Returns via csPtr a description of the colors associated with the Igor color table specified by ictH.

ictH is a handle that you got by calling **GetNamedIgorColorTableHandle**.

startIndex and endIndex specify the indices of the colors for which you want to get a description. startIndex must be between 0 and the number of colors in the table minus one. endIndex must be between startIndex and the number of colors in the table minus one. You can find the number of colors in the table using **GetIgorColorTableInfo**.

The IgorColorSpec structure contains an RGBColor field which identifies the RGB color for a color table entry with a particular index. These structures are defined in IgorXOP.h.

The value field of the IgorColorSpec structure tells you the pixel value that would need to be written to video RAM to get the associated color to appear on the screen when the monitor is in 16 or 256 color mode. It is typically used by advanced programmers who are writing directly to offscreen bitmap memory.

However, when a monitor is running in 16 or 256 color mode, this value is invalidated whenever the system changes the hardware color lookup table, which can happen at any time. If you pass non-zero for the updateVals parameter, then Igor will update the value field for each color before returning it to you and it will be accurate until the next time the system changes the hardware color lookup table. If you pass zero for the updateVals parameter, then Igor will not update the value field and it is likely to be stale.

Updating the value fields takes time so you should pass non-zero for the updateVals parameter only if you really need accurate pixel values. For example, if you just want to know what RGB colors appear in a particular color table then you don't need the pixel values and should pass 0 for the updateVals parameter. On the other hand, if you are writing into an offscreen bitmap in preparation for blasting it to the screen, then you need accurate pixel values and you should pass 1 for updateVals.

The function result is 0 if OK or a non-zero error code.

Thread Safety

GetIgorColorTableValues is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

Command Window

These routines support interacting with the command window.

HistoryDisplaySelection

```
void
HistoryDisplaySelection(void)
```

Scrolls the current selection in the history area into view.

Thread Safety

HistoryDisplaySelection is not thread-safe.

HistoryInsert

```
void
HistoryInsert(dataPtr, dataLen)
char* dataPtr;              // Pointer to text to insert
int dataLen;                // Number of characters to insert
```

Inserts the specified text into the history area, replacing the current selection, if any.

If you just want to append text to the history, call **XOPNotice**, **XOPNotice2** or **XOPNotice3** instead of HistoryInsert.

Except in very rare cases you should not modify the history, except to append to it.

Thread Safety

HistoryInsert is not thread-safe.

HistoryDelete

```
void
HistoryDelete(void)
```

Deletes the currently selected text in the history area.

Except in very rare cases you should not modify the history, except to append to it.

Thread Safety

HistoryDelete is not thread-safe.

HistoryLines

```
int
HistoryLines(void)
```

Returns the total number of lines of text in the history area.

Thread Safety

HistoryLines is not thread-safe.

HistoryGetSelLocs

```
int
HistoryGetSelLocs(startLocPtr, endLocPtr)
TULocPtr startLocPtr;       // Receives location of start of selection
TULocPtr endLocPtr;         // Receives location of end of selection
```

Sets *startLocPtr and *endLocPtr to describe the selected text in the history area.

The TULoc structure is defined in IgorXOPs.h. A text location consists of a paragraph number, starting from zero, and a character position starting from zero.

Returns 0 if OK or an Igor error code.

Thread Safety

HistoryGetSelLocs is not thread-safe.

HistorySetSelLocs

```
int
HistorySetSelLocs(startLocPtr, endLocPtr, flags)
TULocPtr startLocPtr;      // Contains location of start of selection
TULocPtr endLocPtr;        // Contains location of end of selection
int flags;                 // Miscellaneous flags
```

Sets the selection in the history area.

If startLocPtr is NULL, the start location is taken to be the start of history area.

If endLocPtr is NULL, the end location is taken to be the end of history area.

If flags is 1, displays the selection if it is out of view.

Other bits in flags must be set to 0 as they may be used for other purposes in the future.

Returns 0 if OK or an Igor error code.

Returns an error if the start or end locations are out of bounds or if the start location is after the end location.

For the TULoc structure to be valid, its paragraph field must be between 0 and p-1 where p is the number of paragraphs in the history area as reported by HistoryLines. The character position field must be between 0 and c where c is the number of characters in the paragraph as reported by **HistoryFetchParagraphText**. In a paragraph with c characters, the location before the first character corresponds to a position of zero, the location before the last character corresponds to a position of c-1 and the location after the last character corresponds to a position of c.

Thread Safety

HistorySetSelLocs is not thread-safe.

HistoryFetchParagraphText

```
int
HistoryFetchParagraphText(paragraph, textPtrPtr, lengthPtr)
int paragraph;          // Number of paragraph to fetch starting from 0
char* textPtrPtr;       // Receives pointer to text
int* lengthPtr;         // Receives number of characters in paragraph
```

This routine fetches all of the text in the specified paragraph.

If textPtrPtr is not NULL, it returns via textPtrPtr a pointer to the text in the specified paragraph.

Sets *lengthPtr to the number of characters in the paragraph whether textPtrPtr is NULL or not.

textPtrPtr is a pointer to your char* variable. If it is not NULL, Igor allocates a pointer, using **WMNewPtr**, and sets *textPtrPtr to point to the allocated memory. You must dispose this when you no longer need it using **WMDisposePtr**.

Note that the text returned via textPtrPtr is *not* null terminated.

The function result is 0 if OK, an error code if the paragraph is out of range or if an error occurs fetching the text or if the version of Igor that is running does not support this callback.

Example

```
char* p;
int paragraph, length;
int result;

paragraph = 0;
if (result = HistoryFetchParagraphText(paragraph, &p, &length))
   return result;
<Deal with the text pointed to by p>
WMDisposePtr((Ptr)p);
```

Thread Safety

HistoryFetchParagraphText is not thread-safe.

HistoryFetchText

```
int
HistoryFetchText(startLocPtr, endLocPtr, textHPtr)
TULocPtr startLocPtr;      // Identifies start of text to fetch
TULocPtr endLocPtr;        // Identifies end of text to fetch
Handle* textHPtr;          // Receives handle containing text
```

Returns the history area text from the specified start location to the specified end location.

If startLocPtr is NULL, the start location is taken to be the start of history area.

If endLocPtr is NULL, the end location is taken to be the end of history area.

On return, if there is an error, *textHPtr will be NULL. If there is no error, *textHPtr will point to a handle containing the text. *textHPtr belongs to you so dispose it when you are finished with it using **WMDisposeHandle**.

Note that the text in the handle is *not* null terminated. See **Understand the Difference Between a String in a Handle and a C String** on page 221.

The function result is 0 if OK, an error code if an error occurs fetching the text.

Example

```
Handle h = NULL;
int result;

if (result = HistoryFetchSelectedText(NULL, NULL, &h))
   return result;
<Deal with the text in handle>
WMDisposeHandle(h);
```

Thread Safety

HistoryFetchSelectedText is not thread-safe.

Routines for Dealing With Igor Procedures

These routines allow an XOP to get and set procedures in the Igor procedure window. Most XOPs will not need these routines.

GetIgorProcedureList

```
int
GetIgorProcedureList(Handle* hPtr, flags)
Handle* hPtr;
int flags;
```

The main use for this routine is to check if a particular macro or function exists in the Igor procedure windows.

GetIgorProcedureList returns via *hPtr a handle to a semicolon-separated list of procedure names. Depending on the flags parameter, the list may contain names of macros, names of user-defined functions, or names of both macros and user-defined functions.

Note that the text in the handle is *not* null terminated. Use **WMGetHandleSize** to find the number of bytes in the handle. To use C string functions on this text you need to copy it to a local buffer and null-terminate it or add a null terminator to the handle and lock the handle. See **Understand the Difference Between a String in a Handle and a C String** on page 221.

This handle belongs to you, so call **WMDisposeHandle** to dispose it when you no longer need it.

If Igor can not build the list, it returns a non-zero error code and sets *hPtr to NULL.

The flags parameter is defined as follows:

Bit	Meaning
Bit 0	If set, GetIgorProcedureList will list all macros. If cleared, it will ignore all macros.
Bit 1	If set, GetIgorProcedure will list all user-defined functions. If cleared, it will ignore all user-defined functions.
All other bits	Reserved for future use and must be set to 0.

Igor will be unable to build the list if a syntactical error in the procedure files prevents Igor from successfully scanning them. In this case, GetIgorProcedureList will return NEED_COMPILE.

GetIgorProcedureList can also return NOMEM if it runs out of memory. This is unlikely.

Future versions of GetIgorProcedureList may return other error codes so your XOP should not crash or otherwise grossly misbehave if it receives some other error code.

Thread Safety

GetIgorProcedureList is not thread-safe.

GetIgorProcedure

```
int
GetIgorProcedure(procedureName, hPtr, flags)
const char* procedureName;
Handle* hPtr;
int flags;
```

The main use for this routine is to check if a particular macro or function exists in the Igor procedure windows.

If Igor can find the procedure (macro or function) specified by procedureName, GetIgorProcedure returns via *hPtr a handle to the text for the procedure and returns a result of 0. The handle will contain the text for the specified procedure with a carriage return at the end of each line.

Note that the text in the handle is *not* null terminated. Use **WMGetHandleSize** to find the number of bytes in the handle. To use C string functions on this text you need to copy it to a local buffer and null-terminate it or add a null terminator to the handle and lock the handle. See **Understand the Difference Between a String in a Handle and a C String** on page 221. If you pass the handle back to Igor, you must remove the null terminator and unlock the handle.

This handle belongs to you, so call **WMDisposeHandle** to dispose it when you no longer need it.

If Igor can not find the procedure, it returns a non-zero error code and sets *hPtr to NULL.

The flags parameter is defined as follows:

Bit	Meaning
Bit 0	If set, GetIgorProcedure will look for macros with the specified name. If cleared, it will ignore all macros.
Bit 1	If set, GetIgorProcedure will look for user-defined functions with the specified name. If cleared, it will ignore all user-defined functions.
All other bits	Reserved for future use and must be set to 0.

Igor will be unable to find the procedure if there is no such procedure. In this case, GetIgorProcedure will return NO_MACRO_OR_FUNCTION.

Igor will be unable to find the procedure if a syntactical error in the procedure files prevents Igor from successfully scanning them. In this case, GetIgorProcedure will return NEED_COMPILE.

GetIgorProcedure can also return NOMEM if it runs out of memory. This is unlikely.

Future versions of GetIgorProcedure may return other error codes so your XOP should not crash or otherwise grossly misbehave if it receives some other error code.

Thread Safety

GetIgorProcedure is not thread-safe.

SetIgorProcedure

```
int
SetIgorProcedure(procedureName, h, flags)
const char* procedureName;
Handle h;
int flags;
```

This routine was used by very advanced XOPs that added target windows to Igor. It provided a way for XOPs to store recreation macros for their target windows. Adding windows to Igor is no longer supported and use of this routine is no longer recommended. It may be removed in a future version of the XOP Toolkit.

The handle h belongs to Igor. Once you pass it to SetIgorProcedure, you must not modify it, access it, or dispose of it.

Thread Safety

SetIgorProcedure is not thread-safe.

DoWindowRecreationDialog

```
enum CloseWinAction
DoWindowRecreationDialog(procedureName)
char procedureName[MAX_OBJ_NAME+1];
```

This routine was used by very advanced XOPs that added target windows to Igor. It provided a user interface for generation of XOP target window recreation macros. Adding windows to Igor is no longer supported and use of this routine is no longer recommended. It may be removed in a future version of the XOP Toolkit.

Thread Safety

DoWindowRecreationDialog is not thread-safe.

GetFunctionInfo

```
int
GetFunctionInfo(name, fip)
const char* name;
FunctionInfoPtr fip;
```

Returns information that you need in order to call an Igor user function or an external function from an XOP. You might want to do this, for example, to implement your own user-defined curve fitting algorithm. This is an advanced feature that most XOP programmers will not need.

For an overview see **Calling User-Defined and External Functions** on page 197.

name is the name of an existing user or external function. If there is no such function, GetFunctionInfo returns an error. If the function is a user function and procedures are not in a compiled state, GetFunctionInfo returns an error. If everything is OK, GetFunctionInfo returns zero.

When you call GetFunctionInfo with a simple function name, such as "MyFunction", the information returned describes the named function in the currently-executing independent module. If you call GetFunctionInfo with a fully-qualified name, such as "ProcGlobal#MyFunction" or "MyModule#MyFunction", the information returned describes the named function in the named module. So if you want to call from one independent module to another using **CallFunction**, you must use fully-qualified names when calling GetFunctionInfo. If you want to call a function in the built-in ProcGlobal module, it is a good idea to specify it in the function name. See **CallFunction and Igor Independent Modules** on page 198 for an example.

The information returned by GetFunctionInfo should be used and then discarded. If the user does anything to cause procedures to be compiled then the values returned by GetFunctionInfo are no longer valid.

GetFunctionInfo returns via `fip->compilationIndex` a value that you will pass to **CallFunction**. This value is used to make sure that procedures have not been changed between the time you call GetFunctionInfo and the time you call CallFunction.

GetFunctionInfo returns via `fip->functionID` a value which you will pass to CallFunction to specify which user function you want to execute.

GetFunctionInfo returns via `fip->subType` a code that identifies certain special purpose functions. The value returned currently has no use but may be used in the future.

GetFunctionInfo returns via `fip->isExternalFunction` a value that is non-zero for external functions and zero for user functions. This field is for your information only. Your code will be the same for external and user functions.

GetFunctionInfo returns via `fip->returnType` one of the following codes:

```
NT_FP64:                Return value is a double-precision number
NT_FP64 | NT_CMPLX:     Return value is a complex double-precision number
HSTRING_TYPE:           Return value is a string
WAVE_TYPE:              Return value is a wave reference
DATAFOLDER_TYPE:        Return value is a DFREF
FV_NORETURN_TYPE:       No returns value - indicates multiple return function
```

GetFunctionInfo returns via `fip->numOptionalParameters`, `fip->numRequiredParameters` and `fip->totalNumParameters` the number of optional, required and total parameters for the function. Currently, an XOP can call a user function that has optional parameters but the XOP can not pass optional parameters to the function. In other words, it must pass the required parameters only.

GetFunctionInfo returns via `fip->parameterTypes` an array of parameter types. GetFunctionInfo stores a parameter type value in elements 0 through `fip->totalNumParameters-1`. Elements `fip->totalNumParameters` and higher are undefined so you must not use them.

You must use the **CheckFunctionForm** XOPSupport routine to make sure that the function is of the form you want. You normally don't need to examine the parameter type values directly, but in case you are curious, see the comments for GetFunctionInfo in XOPSupport.c.

Parameter type values for numeric, complex numeric and string parameters may be ORed with FV_REF_TYPE. This indicates that the corresponding parameter is "pass-by-reference", meaning that the function can change the value of that parameter.

Return values from functions that use multiple return syntax are treated like pass-by-reference input parameters. See **Calling User-Defined Functions That Return Multiple Results** on page 199.

Thread Safety

GetFunctionInfo is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

The FunctionInfo structure contains an isThreadSafe field which tells you if the function in question is threadsafe.

GetFunctionInfoFromFuncRef

```
int
GetFunctionInfoFromFuncRef(fRef, fip)
FUNCREF fRef;
FunctionInfoPtr fip;
```

Returns information that you need in order to call an Igor user function or an external function from an XOP. You might want to do this, for example, to implement your own user-defined curve fitting algorithm. This is an advanced feature that most XOP programmers will not need.

For an overview see **Calling User-Defined and External Functions** on page 197.

fRef is the value of a FUNCREF field in an Igor Pro structure passed to your XOP as a parameter.

GetFunctionInfoFromFuncRef does not support cross-independent-module calls. It assumes that the FUNCREF passed to it was created in the module that is currently running. There is currently no way to use a FUNCREF to make cross-independent-module calls. Use **GetFunctionInfo** with a qualified name instead.

GetFunctionInfoFromFuncRef will return an error if the function is a user function and procedures are not in a compiled state. If everything is OK, GetFunctionInfoFromFuncRef returns zero.

GetFunctionInfoFromFuncRef works just like **GetFunctionInfo** except that you pass in a FUNCREF instead of the name of the function. See the documentation for GetFunctionInfo for further details.

Thread Safety

GetFunctionInfoFromFuncRef is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

The FunctionInfo structure contains an isThreadSafe field which tells you if the function in question is threadsafe.

CheckFunctionForm

```
int
CheckFunctionForm(fip, requiredNumParameters, requiredParameterTypes,
                                    badParameterNumberPtr, returnType)
FunctionInfoPtr fip;
int requiredNumParameters;
int requiredParameterTypes[];
int* badParameterNumberPtr;
int returnType;
```

Checks the form (number of parameters, types of parameters and return type) of an Igor user-defined or external function against the required form. This is an advanced feature that most XOP programmers will not need.

For an overview see **Calling User-Defined and External Functions** on page 197.

Return values from functions that use multiple return syntax are treated like pass-by-reference input parameters. See **Calling User-Defined Functions That Return Multiple Results** on page 199.

You must call CheckFunctionForm before calling **CallFunction** to make sure that the function you are calling has the form you expect. Otherwise you may cause a crash.

fip is pointer to a structure set by calling **GetFunctionInfo**.

requiredNumParameters is the number of parameters you expect the function to have.

requiredParameterTypes is an array in which you have set each value to one of the following:

```
NT_FP64                       The parameter must be scalar numeric
NT_FP64 | NT_CMPLX            The parameter must be complex numeric
HSTRING_TYPE                  The parameter must be a string
WAVE_TYPE                     The parameter must be a numeric wave
WAVE_TYPE | NT_CMPLX          The parameter must be a numeric wave
TEXT_WAVE_TYPE                The parameter must be a text wave
DATAFOLDER_TYPE               The parameter must be a DFREF
FV_FUNC_TYPE                  The parameter must be a function reference
FV_STRUCT_TYPE | FV_REF_TYPE  The parameter must be a structure
```

The number of elements in requiredParameterTypes must be at least equal to requiredNumParameters.

If the parameter must be pass-by-reference, use FV_REF_TYPE in addition to the values above. For example:

```
NT_FP64 | FV_REF_TYPE
NT_FP64 | NT_CMPLX | FV_REF_TYPE
HSTRING_TYPE | FV_REF_TYPE
FV_STRUCT_TYPE | FV_REF_TYPE
DATAFOLDER_TYPE | FV_REF_TYPE
WAVE_TYPE | FV_REF_TYPE
```

Pass-by-reference is applicable to numeric, string, structure, data folder reference, and wave reference parameters. Structure parameters are always passed by reference.

If you do not want CheckFunctionForm to check a particular parameter, pass -1 in the corresponding element of the requiredParameterTypes array.

For background information see **Structure Parameters** on page 87.

When dealing with a structure parameter, CheckFunctionForm can not guarantee that your XOP and the function you are calling are using the same definition of the structure. See **Structure Parameters** on page 87 for some suggestions for dealing with this problem.

returnType is the required return type of the function which must be one of the following:

```
NT_FP64
NT_FP64 | NT_CMPLX
```

```
HSTRING_TYPE
WAVE_TYPE
DATAFOLDER_TYPE
FV_NORETURN_TYPE
```

FV_NORETURN_TYPE indicates that the function returns multiple values and has no direct result.

CheckFunctionForm sets *badParameterNumberPtr to the zero-based index of the first parameter that does not match the required type or to -1 if all parameters match the required type.

It returns 0 if the form matches the requirements or an error code if not.

If a function parameter type does not match the required parameter type, the error code returned will indicate the type of parameter required but not which parameter type was bad. If you want to inform the user more specifically, use the value returned via badParameterNumberPtr to select your own more specific error code. If the error was a parameter type mismatch, *badParameterNumberPtr will contain the zero-based index of the bad parameter. Otherwise, *badParameterNumberPtr will contain -1.

Wave Parameters

See **CheckFunctionForm and Wave Reference Parameters** on page 202 for a discussion of the rules that CheckFunctionForm applies when checking wave reference parameter compatibility.

Thread Safety

CheckFunctionForm is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

CallFunction

```
int
CallFunction(fip, parameters, resultPtr)
FunctionInfoPtr fip;
void* parameters;
void* resultPtr;
```

Calls the Igor user-defined or external function identified by fip. This is an advanced feature that most XOP programmers will not need.

For an overview see **Calling User-Defined and External Functions** on page 197.

fip is a pointer to a FunctionInfo structure whose values were set by calling **GetFunctionInfo**.

Return values from functions that use multiple return syntax are treated like pass-by-reference input parameters. See **Calling User-Defined Functions That Return Multiple Results** on page 199.

fip->compilationIndex is used by **CallFunction** to make sure that procedures were not recompiled after you called GetFunctionInfo. If procedures were recompiled, then the information in the structure may be invalid so CallFunction returns BAD_COMPILATION_INDEX.

parameters is a pointer to a structure containing the values that you want to pass to the function. These values must agree in type with the function's parameter list, as indicated by the parameter information that you obtain via GetFunctionInfo. To guarantee this, you must call **CheckFunctionForm** before calling CallFunction.

NOTE: The parameters structure must use standard XOP structure packing, namely, two-byte packing. If you don't set the structure packing correctly, a crash is likely. See **Structure Alignment** on page 193.

Parameter type values are discussed in detail in the comments for the GetFunctionInfo function in XOPSupport.c. Here is the basic correspondence between function parameter types and the respective structure field:

```
if (parameterType == NT_FP64)
   structure field is double
```

```
if (parameterType == (NT_FP64 | NT_CMPLX))
   structure field is double[2]

if (parameterType == HSTRING_TYPE)
   structure field is Handle

if (WAVE_TYPE bit is set)
   structure field is waveHndl

if (DATAFOLDER_TYPE bit is set)
   structure field is DataFolderHandle

if (FV_FUNC_TYPE bit is set)
   structure field is PSInt
```

NOTE: For pass-by-value strings parameters, ownership of a handle stored in the parameter structure is passed to the function when you call CallFunction. The function will dispose the handle and CallFunction will set the field to NULL. You must not dispose it or otherwise reference it after calling CallFunction.

NOTE: For pass-by-reference string parameters, the handle stored in the parameter structure field may be reused or disposed by the called function. When CallFunction returns, you own the handle which may be the same handle you passed or a different handle. You own this handle and you must dispose it when you no longer need it. If the field is NULL, which could occur in the event of an error, you must not dispose of it or otherwise access it.

CallFunction stores the function result at the location indicated by resultPtr. Here is the correspondence between the function result type and the variable pointed to by resultPtr:

```
NT_FP64               double
NT_FP64 | NT_CMPLX    double[2]
HSTRING_TYPE          Handle
WAVE_TYPE             waveHndl
DATAFOLDER_TYPE       DataFolderHandle
```

However, if the function result type is FV_NORETURN_TYPE, this means that the function uses multiple return syntax and has no direct result. In this case, and only in this case, CallFunction ignores resultPtr and you should pass nullptr for it.

NOTE: A function that returns a string, wave or DataFolderHandle can return NULL instead of a valid handle. You must test the returned value to make sure it is not NULL before using it. If the returned handle is not NULL, you own it and you must dispose it when you no longer need it.

NOTE: For string return values, if the returned handle is not NULL, you own it and you must dispose it when you no longer need it.

CallFunction returns 0 as the function result if the function executed. If the function could not be executed, it returns a non-zero error code.

Thread Safety

CallFunction is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

You can call a thread-safe user-defined function or external function while you are running an an Igor preemptive thread. You can tell if you are running in a thread by calling **RunningInMainThread**.

When you call **GetFunctionInfo**, you receive information about the function in a FunctionInfo structure. The FunctionInfo structure contains an isThreadSafe field. If you are running in a thread, you can check the isThreadSafe field to make sure the function you are calling is threadsafe.

If you try to call a non-threadsafe function from a thread using CallFunction, Igor will return an error, typically the ONLY_THREADSAFE ("Function must be ThreadSafe") error.

GetIgorCallerInfo

```
int
GetIgorCallerInfo(pathOrTitle, linePtr, routineName, callStackHPtr)
char pathOrTitle[MAX_PATH_LEN+1];
int* linePtr;
char routineName[256];
Handle* callStackHPtr;
```

Returns information about the Igor procedure that is currently running. This may be useful for debugging purposes in complex Igor projects.

If the currently running procedure is stored in a standalone file then the full path to the procedure file is returned in Macintosh HFS format (using colon separators) via pathOrTitle.

If the currently running procedure is in the built-in procedure window or in a packed procedure file or in a new procedure file not yet saved to disk then the window's title is returned via pathOrTitle preceded by a colon (e.g., ":Procedure").

If no procedure is running then pathOrTitle is set to an empty string ("").

If a procedure is running then *linePtr is set to the zero-based line number within the file.

When a macro is running this returns the line number of the macro declaration.

When a user-defined function is running it returns the line number of the statement which is currently executing.

If no procedure is running then *linePtr is set to -1.

If a procedure is running then the name of the procedure is returned via routineName. Otherwise routineName is set an empty string ("").

If GetIgorCallerInfo returns zero then the function has succeeded and you own the handle referenced by callStackHPtr, and you must dispose it.

If GetIgorCallerInfo returns a non-zero error code then *stackInfoHPtr is undefined and you must not do anything with it.

If a procedure is running, *callStackHPtr is set to a handle containing a stack crawl.

If no procedure is running, *callStackHPtr is set to NULL. You should always test *callStackHPtr - do not use it if it is NULL. If *callStackHPtr is not NULL then this handle belongs to you and you must dispose it when you no longer need it.

If *callStackHPtr is not NULL it contains a list of Igor procedures separated by semicolons. *callStackHPtr is not null terminated. Use **WMGetHandleSize** to determine the size of the stack crawl text.

In some cases the currently running procedure can not be determined, for example because because Igor procedures need to be compiled. If so then GetIgorCallerInfo acts as if no procedure is running.

Thread Safety

GetIgorCallerInfo is not thread-safe.

GetIgorRTStackInfo

```
int
GetIgorRTStackInfo(code, stackInfoHPtr)
Int code;
Handle* stackInfoHPtr;
```

Returns information about the chain of Igor procedure that are currently running. This may be useful for debugging purposes in complex Igor projects.

If GetIgorRTStackInfo returns zero then the function has succeeded and you own the handle referenced by stackInfoHPtr, and you must dispose it.

If GetIgorRTStackInfo returns a non-zero error code then *stackInfoHPtr is undefined and you must not do anything with it.

The contents of the string returned by GetIgorRTStackInfo is the same as the contents of the string returned by the built-in Igor function GetRTStackInfo. See the documentation for GetRTStackInfo for details.

The string stored in *stackInfoHPtr is not null terminated. Use **WMGetHandleSize** on *stackInfoHPtr to determine the size of the text.

Thread Safety

GetIgorRTStackInfo is not thread-safe.

Multithreading Support Routines

These routines support multithreading.

RunningInMainThread

```
int
RunningInMainThread(void)
```

Returns 1 if you are running in the main thread, 0 if you are running in another thread.

For general information on multithreaded XOPs, see Chapter 10, **Multithreading**.

Thread Safety

RunningInMainThread is thread-safe. It can be called from any thread.

CheckRunningInMainThread

```
int
CheckRunningInMainThread(routineName)
const char* routineName;      // Name of the calling routine.
```

CheckRunningInMainThread is called by non-thread-safe XOPSupport routines to provide the XOP programmer with feedback if the XOP calls a non-threadsafe XOPSupport routine from a thread other than the main thread. In this event, it displays an error dialog.

To avoid a cascade of such dialogs, the dialog is presented only once per minute.

The return value is the truth that you are running in the main thread.

You can call CheckRunningInMainThread from your own code to provide feedback if your non-threadsafe routine is called from a pre-emptive thread. It is typically used as follows:

```
if (!CheckRunningInMainThread("SomeRoutineName"))
   return NOT_IN_THREADSAFE;  // NOT_IN_THREADSAFE is an Igor error code.
}
```

For general information on multithreaded XOPs, see Chapter 10, **Multithreading**.

Thread Safety

CheckRunningInMainThread is not thread-safe but can be used to alert the XOP programmer if a non-threadsafe function is mistakenly called from a preemptive thread.

ThreadGroupPutDF

```
int
ThreadGroupPutDF(threadGroupID, dataFolderH)
int threadGroupID;
DataFolderHandle dataFolderH;
```

ThreadGroupPutDF is used to pass data folders between Igor threads by way of an Igor-maintained queue. It snips the specified data folder from the data hierarchy of the calling thread and posts it to a queue from which it can be retrieved by calling **ThreadGroupGetDF** from a different thread.

When called from the main thread, ThreadGroupPutDF removes the specified data folder from the main thread's data hierarchy and posts it to the input queue of the Igor thread group specified by threadGroupID. You would do this to pass a data folder to an Igor preemptive thread for processing.

When called from an Igor preemptive thread, ThreadGroupPutDF removes the specified data folder from the running thread's data hierarchy and posts it to the output queue of the thread group. You would do this to pass data from an Igor preemptive thread to the main thread. In this case, threadGroupID is ignored and you can pass 0 for it.

threadGroupID is a thread group ID passed to you from a calling user-defined function or 0 as described above. See the Igor documentation for ThreadGroupCreate for further discussion of thread group IDs.

dataFolderH is a handle to the data folder to be removed from the currently-running Igor thread's data hierarchy and transferred to the thread group's input queue or output queue as described above.

dataFolderH must be a valid data folder handle. It must not be NULL.

If ThreadGroupPutDF succeeds, the specified data folder handle is no longer valid and must not be further used.

See the Igor documentation for the ThreadGroupPutDF operation for further details and warnings.

For general information on multithreaded XOPs, see Chapter 10, **Multithreading**.

Thread Safety

ThreadGroupPutDF is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

ThreadGroupGetDF

```
int
ThreadGroupGetDF(threadGroupID, waitMilliseconds, dataFolderHPtr)
int threadGroupID;
int waitMilliseconds;   // Milliseconds to wait for data folder
DataFolderHandle* dataFolderHPtr;
```

ThreadGroupGetDF is used to pass data folders between Igor threads by way of an Igor-maintained queue. It removes a data folder from the queue, if one is available, and stitches it into the data hierarchy of the currently running Igor thread.

When called from the main thread, ThreadGroupGetDF returns a data folder from the output queue of the thread group specified by threadGroupID or NULL if there are no data folders in the queue. If a data folder is available, it is stitched into the main thread's data hierarchy. You would do this to move results from an Igor preemptive thread into the main thread for display and further processing.

When called from an Igor preemptive thread, ThreadGroupGetDF returns a data folder from the input queue of the currently running Igor thread's thread group or NULL if there are no data folders in the queue. You would do this to get input from the main thread into the Igor premptive thread. If a data folder is available, it is stitched into the currently-running Igor thread's data hierarchy. In this case, threadGroupID is ignored and you can pass 0 for it.

threadGroupID is a thread group ID passed to you from a calling user-defined function or 0 as described above. See the Igor documentation for ThreadGroupCreate for further discussion of thread group IDs.

waitMilliseconds is the number of milliseconds to wait to see if a data folder becomes available in the queue. Pass 0 to test if a data folder is available immediately. The value for waitMilliseconds must be between 0 and 2147483647 (2^31-1 milliseconds - about 25 days).

*dataFolderHPtr is set to NULL if no data folders are available or to a handle to the data folder that was retrieved from the queue. Igor changes the name of the data folder if that is necessary to make it unique within its parent data folder.

On return, check the function result from ThreadGroupGetDF and *dataFolderHPtr. If the function result is 0 and *dataFolderHPtr is not NULL then *dataFolderHPtr is a valid data folder handle in the currently-running thread's data hierarchy.

See the Igor documentation for the ThreadGroupGetDF operation for further details and warnings.

For general information on multithreaded XOPs, see Chapter 10, **Multithreading**.

Thread Safety

ThreadGroupGetDF is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

Windows-Specific Routines

These routines are available and applicable to XOPs running under the Windows OS only.

XOPModule

```
HMODULE
XOPModule(void)
```

This routine is supported on Windows only.

XOPModule returns the XOP's module handle.

You will need this HMODULE if your XOP needs to get resources from its own executable file using the Win32 FindResource and LoadResource routines. It is also needed for other Win32 API routines.

Thread Safety

XOPModule is thread-safe. It can be called from any thread.

IgorModule

```
HMODULE
IgorModule(void)
```

This routine is supported on Windows only.

IgorModule returns Igor's module handle.

There is probably no reason for an XOP to call this routine.

Thread Safety

IgorModule is thread-safe. It can be called from any thread.

IgorClientHWND

```
HWND
IgorClientHWND(void)
```

This routine is supported on Windows only.

IgorClientHWND returns Igor's MDI client window HWND.

Some Win32 API calls require that you pass an HWND to identify the owner of a new window or dialog. An example is MessageBox. You must pass IgorClientHWND() for this purpose.

Thread Safety

IgorClientHWND is thread-safe. It can be called from any thread.

WMGetLastError

```
int
WMGetLastError(void)
```

This routine is supported on Windows only.

WMGetLastError does the same as the Win32 GetLastError routine except for three things. First, it translates Windows OS error codes into codes that mean something to Igor. Second, it always returns a non-zero result whereas GetLastError can sometimes return 0. Third, it calls SetLastError(0).

For a detailed explanation, see **Handling Windows OS Error Codes** on page 60.

Thread Safety

WMGetLastError is thread-safe. It can be called from any thread. It relies on the Windows GetLastError function which uses per-thread storage to store an error code for each thread.

WindowsErrorToIgorError

```
int
WindowsErrorToIgorError(int winErr)
int winErr;              // Windows OS error code
```

This routine is supported on Windows only.

WindowsErrorToIgorError takes a Windows OS error code and returns an error code that means something to Igor.

For a detailed explanation, see **Handling Windows OS Error Codes** on page 60**.**

Thread Safety

WindowsErrorToIgorError is thread-safe. It can be called from any thread.

Miscellaneous Routines

These routines don't fit in any particular category.

XOPCommand

```
int
XOPCommand(cmdPtr)
char* cmdPtr;               // C string containing an Igor command
```

Submits a command to Igor for execution.

The function result is 0 if OK or an error code.

Use this to access Igor features for which there is no direct XOP interface.

cmdPtr is a null-terminated C string. The string must consist of one line of text not longer than MAXCMDLEN and with no carriage return characters.

A side-effect of XOPCommand is that it causes Igor to do an update. See **DoUpdate** for a definition of "update".

XOPCommand displays the command in Igor's command line while it is executing. If you don't want the command to be shown in the command line, which is usually the case, use **XOPCommand2**, **XOPCommand3** or **XOPSilentCommand** instead of XOPCommand.

XOPCommand does not send the executed command to the history area.

Liberal names of waves and data folders must be quoted before using them in the Igor command line. Use **PossiblyQuoteName** when preparing the command to be executed so that your XOP works with liberal names.

NOTE: If your XOP adds a window to Igor or if the command that you are executing directly or indirectly calls your XOP again, this callback will cause recursion. This can cause your XOP to crash if you do not handle it properly. See **Handling Recursion** on page 66 for details.

Thread Safety

XOPCommand is not thread-safe.

XOPCommand2

```
int
XOPCommand2(cmdPtr, silent, sendToHistory)
char* cmdPtr;               // C string containing an Igor command
int silent;                 // True to not show cmd in command line
int sendToHistory;          // True to send cmd to history area
```

Submits a command to Igor for execution.

The function result is 0 if OK or an error code.

Use this to access Igor features for which there is no direct XOP interface.

cmdPtr is a null-terminated C string. The string must consist of one line of text not longer than MAXCMDLEN and with no carriage return characters.

If silent is non-zero, the command is displayed in Igor's command line while it executes.

If sendToHistory is non-zero and the command generates no error, the command is sent to the history area after execution.

A side-effect of XOPCommand2 is that it causes Igor to do an update. See **DoUpdate** below for a definition of "update".

Liberal names of waves and data folders must be quoted before using them in the Igor command line. Use **PossiblyQuoteName** when preparing the command to be executed so that your XOP works with liberal names.

NOTE: If your XOP adds a window to Igor or if the command that you are executing directly or indirectly calls your XOP again, this callback will cause recursion. This can cause your XOP to crash if you do not handle it properly. See **Handling Recursion** on page 66 for details.

Thread Safety

XOPCommand2 is not thread-safe.

XOPCommand3

```
int
XOPCommand3(cmdPtr, silent, sendToHistory, historyTextHPtr)
char* cmdPtr;               // C string containing an Igor command
int silent;                 // True to not show cmd in command line
int sendToHistory;          // True to send cmd to history area
Handle* historyTextHPtr;    // Receives history text generated by command.
```

This is just like **XOPCommand2** except that it returns via historyTextHPtr a handle containing any text added to the history by the command. In the event of an error, *historyTextHPtr is set to NULL. If no error occurs, *historyTextHPtr is set to a new handle which you own and must dispose using **WMDisposeHandle**. *historyTextHPtr is not null terminated.

The function result is 0 if OK or an error code.

Thread Safety

XOPCommand3 is not thread-safe.

XOPSilentCommand

```
int
XOPSilentCommand(cmdPtr)
char* cmdPtr;               // C string containing an Igor command
```

Submits a command to Igor for execution.

The function result is 0 if OK or an error code.

Use this to access Igor features for which there is no direct XOP interface.

A side-effect of XOPSilentCommand is that it causes Igor to do an update. See **DoUpdate** for a definition of “update”.

This is just like **XOPCommand** except that it does not display the command in Igor’s command line as it is executing.

XOPCommand does not send the executed command to the history area.

Liberal names of waves and data folders must be quoted before using them in the Igor command line. Use **PossiblyQuoteName** when preparing the command to be executed so that your XOP works with liberal names.

NOTE: If your XOP adds a window to Igor or if the command that you are executing directly or indirectly calls your XOP again, this callback will cause recursion. This can cause your XOP to crash if you do not handle it properly. See **Handling Recursion** on page 66 for details.

Thread Safety

XOPSilentCommand is not thread-safe.

DoUpdate

```
void
DoUpdate(void)
```

Causes Igor to do an immediate update.

An update consists of:

- Redrawing any windows that have been uncovered
- Re-evaluating any dependency formulas (e.g., wave0 := K0 when K0 changes)
- Redrawing windows displaying waves that have changed

Igor does updates automatically in its outer loop. You should call DoUpdate *only* if you want Igor to do an update *before* your XOP returns to Igor.

NOTE: If your XOP adds a window to Igor or if the update of an Igor window indirectly calls your XOP again, this callback will cause recursion. This can cause your XOP to crash if you do not handle it properly. See **Handling Recursion** on page 66 for details.

Thread Safety

DoUpdate is not thread-safe.

PauseUpdate

```
void
PauseUpdate(savePtr)
int* savePtr;              // Place to save current state of PauseUpdate
```

Tells Igor not to update graphs and tables until your XOP calls ResumeUpdate.

Make sure to balance this with a ResumeUpdate call.

Thread Safety

PauseUpdate is not thread-safe.

ResumeUpdate

```
void
ResumeUpdate(savePtr)
int* savePtr;              // Previous state from PauseUpdate call
```

Undoes effect of previous PauseUpdate.

Make sure this is balanced with a previous PauseUpdate call.

Thread Safety

ResumeUpdate is not thread-safe.

XOPNotice

```
void
XOPNotice(noticePtr)
char* noticePtr;           // Message for Igor's history area
```

Displays the C string pointed to by noticePtr in Igor's history.

This is used mostly for debugging or to display the results of an operation.

XOPNotice prints only the first MAXCMDLEN-2 (currently 398) bytes of the specified message.

NOTE: When Igor passes a message to you, you *must* get the message, using **GetXOPMessage**, and get all of the arguments, using **GetXOPItem**, *before* doing any callbacks, including XOPNotice. The reason for this is that the act of doing the callback overwrites the message and arguments that Igor is passing to you.

Thread Safety

XOPNotice is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

Igor queues text sent to the history area from a preemptive thread and sends the text to the history area in the main thread. Consequently text from different threads will appear in the history in unpredictable order.

XOPNotice2

```
void
XOPNotice2(noticePtr, options)
char* noticePtr;           // Message for Igor's history area
UInt32 options;
```

Displays the C string pointed to by noticePtr in Igor's history.

This is used mostly for debugging or to display the results of an operation.

XOPNotice2 is the same as **XOPNotice** except that it allows you to prevent marking the current experiment to be marked as modified.

options is defined as follows:

Bit	Meaning
Bit 0	If cleared, the modification state of the history area is not modified. Use this if you want to display a notice but don't want that to cause the current experiment to be modified. If set, the history area is marked as modified after the notice is displayed.
All other bits	Reserved. You must pass zero for these bits.

XOPNotice2 prints only the first MAXCMDLEN-2 (currently 398) bytes of the specified message.

NOTE: When Igor passes a message to you, you *must* get the message, using **GetXOPMessage**, and get all of the arguments, using **GetXOPItem**, *before* doing any callbacks, including XOPNotice2. The reason for this is that the act of doing the callback overwrites the message and arguments that Igor is passing to you.

Thread Safety

XOPNotice2 is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

Igor queues text sent to the history area from a preemptive thread and sends the text to the history area in the main thread. Consequently text from different threads will appear in the history in unpredictable order.

XOPNotice3

```
void
XOPNotice3(noticePtr, rulerName, options)
char* noticePtr;           // Message for Igor's history area
char* rulerName;           // Name of ruler in history carbon copy
int options;
```

Displays the C string pointed to by noticePtr in Igor's history.

Through the rulerName and options parameters, XOPNotice3 provides control over the formatting of the text in the History Carbon Copy notebook. If you are not using the History Carbon Copy feature, use XOPNotice instead of XOPNotice3.

noticePtr is a null-terminated C string. Typically notices should be terminated by carriage return (use CR_STR at end of string as shown below).

rulerName is the name of a ruler in the History Carbon Copy notebook. XOPNotice3 applies the ruler to the current selection in the History Carbon Copy notebook before inserting the text. If rulerName is "" then the ruler is not changed.

options is defined as follows:

Bit	Meaning
Bit 0	If set, the history carbon copy ruler is restored after the text is inserted. If cleared, the history carbon copy ruler is not restored.
All other bits	Reserved. You must pass zero for these bits.

Typically you would call this to use a ruler that you previously created in the history carbon copy notebook to control formatting for specific kinds of notices. For example, if you created a ruler named Warning, you would send a warning to the history like this:

```
XOPNotice3("You have been warned!" CR_STR, "Warning", 1);
```

Bit 0 of options should be set except in the case when you expect to make many calls to XOPNotice3 in a row. In this case, you can make it run slightly faster like this:

```
XOPNotice3("Starting", "Progress", 0);     // Starting a long process
XOPNotice3(" .", "", 0);                   // Add a dot to indicate progress
. . .
XOPNotice3(" .", "", 0);                   // Add a dot to indicate progress
XOPNotice3("Done!" CR_STR, "", 0);         // The long process is done
XOPNotice3("", "Normal", 0);               // Restore to normal ruler
```

In this example, we set the history carbon copy ruler to "Progress" which is the name of a ruler that we created for paragraphs containing progress messages. We then called XOPNotice3 repeatedly to add a dot to the progress message. In these calls, we specified no ruler so the ruler is not changed. At the end, we add a carriage return (CR_STR) to make sure we are on a new paragraph and then set the ruler to Normal so that normal history carbon copy processing will occur in the future.

XOPNotice3 prints only the first MAXCMDLEN-2 (currently 398) bytes of the specified message.

NOTE: When Igor passes a message to you, you *must* get the message, using **GetXOPMessage**, and get all of the arguments, using **GetXOPItem**, *before* doing any callbacks, including XOPNotice3. The reason for this is that the act of doing the callback overwrites the message and arguments that Igor is passing to you.

Thread Safety

XOPNotice3 is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

Igor queues text sent to the history area from a preemptive thread and sends the text to the history area in the main thread. Consequently text from different threads will appear in the history in unpredictable order.

XOPResNotice

```
void
XOPResNotice(strListID, index)
int strListID;             // Resource ID to get string from
int index;                 // String number in that resource
```

NOTE: XOPResNotice is antiquated. Use **XOPNotice** or **XOPNotice2** instead.

Gets a string from an STR# resource in the XOP's resource fork and displays it in Igor's history.

The resource must be of type 'STR#'. The resource ID should be between 1100 and 1199.

These resource IDs are reserved for XOPs.

strListID is the resource ID of the STR# containing the string.

index is the number of the string in the STR# resource.

XOPResNotice prints only the first MAXCMDLEN-2 (currently 398) bytes of the specified message.

Thread Safety

XOPResNotice is not thread-safe.

WaveList

```
int
WaveList(listHandle, match, sep, options)
Handle listHandle;         // Handle to contain list of waves
char* match;               // "*" for all waves or match pattern
char* sep;                 // Separator character, normally ";"
char* options;             // Options for further selection of wave
```

Puts a list of waves from the current data folder that match the parameters into listHandle.

The function result is 0 if OK or an error code if the parameters were not legal or another problem (such as out of memory) occurred.

On input, listHandle is a handle to 0 bytes which you have allocated, typically with **WMNewHandle**.

Note that the text in the handle is *not* null terminated. Use **WMGetHandleSize** to find the number of bytes in the handle. To use C string functions on this text you need to copy it to a local buffer and null-terminate it or add a null terminator to the handle and lock the handle. See **Understand the Difference Between a String in a Handle and a C String** on page 221. If you pass the handle back to Igor, you must remove the null terminator and unlock the handle.

The meaning of the match, sep and options parameters is the same as for the built-in Igor WaveList function.

The handle must be allocated and disposed by the calling XOP.

Thread Safety

WaveList is not thread-safe.

WinList

```
int
WinList(listHandle, match, sep, options)
Handle listHandle;         // Handle to contain list of windows
char* match;               // "*" for all windows or match pattern
char* sep;                 // Separator character, normally ";"
char* options;             // Options for further selection of windows
```

Puts a list of windows that match the parameters into listHandle.

The function result is 0 if OK or an error code if the parameters were not legal or another problem (such as out of memory) occurred.

The meaning of the match parameter is the same as for the built-in Igor WinList function.

If options is "" then all windows are selected.

If options is "WIN:" then just the target window is selected.

If options is "WIN:typeMask" then windows of the specified types are selected.

The window type masks are defined in IgorXOP.h.

On input, listHandle is a handle to 0 bytes which you have allocated using **WMNewHandle**.

Note that the text in the handle is *not* null terminated. Use **WMGetHandleSize** to find the number of bytes in the handle. To use C string functions on this text you need to copy it to a local buffer and null-terminate it or add a null terminator to the handle and lock the handle. See **Understand the Difference Between a String in a Handle and a C String** on page 221. If you pass the handle back to Igor, you must remove the null terminator and unlock the handle.

The handle must be allocated and disposed by the calling XOP.

Thread Safety

WinList is not thread-safe.

PathList

```
int
PathList(listHandle, match, sep, options)
Handle listHandle;          // Handle to contain list of paths
char* match;                // "*" for all paths or match pattern
char* sep;                  // Separator character, normally ";"
char* options;              // Must be ""
```

Puts a list of symbolic paths that match the parameters into listHandle.

The function result is 0 if OK or an error code if the parameters were not legal or another problem (such as out of memory) occurred.

The meaning of the match parameter is the same as for the built-in Igor PathList function.

options must be "".

On input, listHandle is a handle to 0 bytes which you have allocated using **WMNewHandle**.

Note that the text in the handle is *not* null terminated. Use **WMGetHandleSize** to find the number of bytes in the handle. To use C string functions on this text you need to copy it to a local buffer and null-terminate it or add a null terminator to the handle and lock the handle. See **Understand the Difference Between a String in a Handle and a C String** on page 221. If you pass the handle back to Igor, you must remove the null terminator and unlock the handle.

The handle must be allocated and disposed by the calling XOP.

Thread Safety

PathList is not thread-safe.

GetPathInfo2

```
int
GetPathInfo2(pathName, fullDirPath)
const char* pathName;               // Input
char* fullDirPath[MAX_PATH_LEN+1];  // Output
```

pathName is the name of an Igor symbolic path.

Returns via fullDirPath the full native path to the directory referenced by pathName. The returned path includes a trailing colon on Macintosh and a trailing backslash on Windows.

The function result is 0 if OK or an error code if the pathName is not the name of an existing Igor symbolic path.

Thread Safety

GetPathInfo2 is thread-safe.

VariableList

```
int
VariableList(listHandle, match, sep, varTypeCode)
Handle listHandle;         // Receives list of variable names
char* match;               // "*" for all variables or match pattern
char* sep;                 // Separator character, normally ";"
char* varTypeCode;         // Select which variable types to list
```

Puts a list of Igor global numeric variable names from the current data folder that match the parameters into listHandle.

The function result is 0 if OK or an error code if the parameters were not legal or another problem (such as out of memory) occurred.

match and sep are as for the WaveList callback.

varTypeCode is some combination of NT_FP32, NT_FP64 and NT_CMPLX. Use (NT_FP32 | NT_FP64 | NT_CMPLX) to get all variables. All numeric global variables are double precision.

On input, listHandle is a handle to 0 bytes which you have allocated using **WMNewHandle**. VariableList fills the handle with text.s

Note that the text in the handle is *not* null terminated. Use **WMGetHandleSize** to find the number of bytes in the handle. To use C string functions on this text you need to copy it to a local buffer and null-terminate it or add a null terminator to the handle and lock the handle. See **Understand the Difference Between a String in a Handle and a C String** on page 221. If you pass the handle back to Igor, you must remove the null terminator and unlock the handle.

The handle must be allocated and disposed by the calling XOP.

Thread Safety

VariableList is not thread-safe.

StringList

```
int
StringList(listHandle, match, sep)
Handle listHandle;         // Receives list of string variable names
char* match;               // "*" for all strings or match pattern
char* sep;                 // Separator character, normally ";"
```

Puts a list of Igor global string variable names from the current data folder that match the parameters into listHandle.

The function result is 0 if OK or an error code if the parameters were not legal or another problem (such as out of memory) occurred.

match and sep are as for the WaveList callback.

On input, listHandle is a handle to 0 bytes which you have allocated using **WMNewHandle**. StringList fills the handle with text.

Note that the text in the handle is *not* null terminated. Use **WMGetHandleSize** to find the number of bytes in the handle. To use C string functions on this text you need to copy it to a local buffer and null-terminate it or add a null terminator to the handle and lock the handle. See **Understand the Difference Between a String in a Handle and a C String** on page 221. If you pass the handle back to Igor, you must remove the null terminator and unlock the handle.

The handle must be allocated and disposed by the calling XOP.

Thread Safety

StringList is not thread-safe.

CheckAbort

```
int
CheckAbort(timeoutTicks)
TickCountInt timeoutTicks;    // Ticks at which timeout occurs
```

Use this to check if it's time to stop an operation or if user is pressing cmd-dot (Macintosh) or Ctrl-Break (Windows) to abort it.

Returns -1 if user is now pressing cmd-dot (Macintosh) or Ctrl-Break (Windows).

Returns 1 if timeoutTicks is not zero and TickCount > timeoutTicks. TickCount is the Macintosh tick counter. It increments approximately 60 times per second. The TickCount function is emulated by Igor when running on Windows.

Returns 0 otherwise.

CheckAbort this does a check only every .1 second no matter how often you call it.

CheckAbort *only* checks if the abort key combinations listed above are pressed. It does not check if an abort occurs in Igor which would happen if the user presses the abort keys or clicks the Abort button in the status bar on Windows or if a procedure calls the Abort operation. For most purposes, use **SpinProcess**, which checks for all types of aborts, instead of CheckAbort. Use CheckAbort if SpinProcess, which calls back to Igor, would be too slow.

On Macintosh this routine may not work correctly on non-English keyboards. It checks the key that is the dot key on an English keyboard. This is the key that is two keys to the left of the righthand shift key. On a French keyboard, for example, that is the colon key so you must press cmd-colon instead of cmd-dot.

If this is a problem, you may prefer to use the CheckEventQueueForUserCancel function from the Carbon library instead of CheckAbort. However CheckEventQueueForUserCancel checks for the escape key in addition to cmd-dot. It also removes events from the event queue which may prevent Igor from detecting that you want to abort procedure execution.

See **Checking For Aborts** on page 203 for further discussion.

Thread Safety

CheckAbort is thread-safe. It can be called from any thread.

IgorError

```
void
IgorError(title, errCode)
char* title;                // Short title for error alert
int errCode;                // Error code
```

Displays an error alert appropriate for the specified error code.

Title is a short string that identifies what generated the error.

errCode may be an Igor error code (defined in IgorXOP.h), an XOP-defined error code, or, when running on Macintosh, a Mac OS error code. To display a message for a Windows OS error, convert the code to an Igor code by calling **WindowsErrorToIgorError**.

Use this routine when an error occurs in an XOP but not during the execution of a command line operation, function or menu item routine. See **XOP Errors** on page 59 for details.

Thread Safety

IgorError is not thread-safe.

GetIgorErrorMessage

```
int
GetIgorErrorMessage(errCode, errorMessage)
int errCode;                // Error code
char errorMessage[256];     // Output string goes here
```

Returns via errorMessage the message corresponding to the specified error code.

errCode may be an Igor error code (defined in IgorXOP.h), an XOP-defined error code, or, when running on Macintosh, a Mac OS error code. To obtain a message for a Windows OS error, convert the code to an Igor code by calling **WindowsErrorToIgorError** before calling GetIgorErrorMessage.

Do not pass 0 for errCode. There is no error message corresponding to 0.

errorMessage must be large enough to hold 255 bytes plus a trailing null.

The function result is 0 if OK, or a non-zero error code if the errCode parameter is invalid. If GetIgorErrorMessage fails to get a message, it sets *errorMessage to 0.

This routine is of use when you want to display an error message in your own window rather than in a dialog. See **XOP Errors** on page 59 for details.

Thread Safety

GetIgorErrorMessage is not thread-safe.

SpinProcess

```
int
SpinProcess(void)
```

When running in the main thread, SpinProcess spins the beach ball cursor, updates progress windows and does other tasks that need to be done periodically.

Whether called from the main thread or from an Igor preemptive thread, SpinProcess returns the truth that your external operation or function should abort because:

The user has requested an abort

A user-defined function called the Abort operation

An error has occurred that requires an abort

NOTE: If your XOP adds a window to Igor or if the update of an Igor window indirectly calls your XOP again, this callback will cause recursion. This can cause your XOP to crash if you do not handle it properly. See **Handling Recursion** on page 66 for details.

See **Checking For Aborts** on page 203 for further discussion.

Thread Safety

SpinProcess is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

PutCmdLine

```
void
PutCmdLine(cmd, mode)
char* cmd;
int mode;
```

This is a lower level call than the **FinishDialogCmd** call which should be used in most cases.

Puts the text in the C string cmd into Igor's command line using the specified mode.

Liberal names of waves and data folders must be quoted before using them in the Igor command line. Use **PossiblyQuoteName** when preparing the command to be executed so that your XOP works with liberal names.

Modes are:

Mode	Meaning
INSERTCMD	Inserts text at current insertion point.
FIRSTCMD	Inserts text in front of command buffer.
FIRSTCMDCRHIT	Inserts text in front of command buffer, set crHit.
REPLACEFIRSTCMD	Replaces first line of command buffer with text.
REPLACEALLCMDSCRHIT	Replaces all lines and set crHit.
REPLACEALLCMDS	Replaces all lines of command buffer with text.

The intended use for PutCmdLine is to put a command generated by an XOP dialog into Igor's command line. For this, use the FIRSTCMD mode to just put the command in the command line or the FIRSTCMD-CRHIT mode to put the command in the command line and start execution of the command buffer. crHit is a variable within Igor itself which enables execution of commands in the command buffer. Execution of commands occurs in Igor's idle loop.

If you just want to submit a command to Igor for immediate execution, use **XOPCommand**, **XOPCommand2**, **XOPCommand3** or **XOPSilentCommand** instead.

Thread Safety

PutCmdLine is not thread-safe.

XOPDisplayHelpTopic

```
int
XOPDisplayHelpTopic(title, topicStr, flags)
const char* title;          // Title for help window
const char* topicStr;       // The help topic to be displayed
int flags;
```

Displays help from an Igor help file for the specified topic. See **Igor Pro Help File** on page 207 for background information.

The title parameter is used only for modal help and supplies the title for a modal dialog containing the help. Modal help is described below.

topicStr is a help topic string that matches a help topic or subtopic in an Igor help file. Igor first searches open help files for the topic. If it is not found, Igor then searches all Igor help files in the folder containing the XOP file and subfolders. If it is still not found Igor then searches all Igor help files in the Igor Pro folder and subfolders.

The help file must be compiled in order for Igor to find the topic. Each time you open a file as a help file, Igor checks to see if it is compiled and if not asks if you want to compile it.

topicStr may have one of the following formats:

Format	Example
<topic name>	"SimpleLoadWave XOP"
<subtopic name>	"SimpleLoadWave"
<topic name>[<subtopic name>]	"SimpleLoadWave XOP[SimpleLoadWave]"

If the topic that you want to display is a subtopic, you should use the last form since it minimizes the chance that Igor will find another help file with the same subtopic name. Also, you must choose descriptive topic and subtopic names to minimize the chance of a conflict between two help files.

Note that once you reference a help topic or subtopic from your executable code, you must be careful to avoid changing the name of the topic or subtopic.

The flags parameter is interpreted bitwise as follows:

Bit	Meaning
Bit 0	If cleared, Igor displays non-modal help. If set, Igor displays modal help.
Bit 1	If cleared, during modal help Igor displays the entire help file (if it is not too big) in the modal help dialog, with the specified topic initially in view. If set, during modal help Igor displays just the specified topic.
Bit 2	If cleared, if the topic can not be found Igor displays an error dialog. If set, if the topic can not be found Igor does not display an error dialog.
All other bits	Reserved. You must pass zero for these bits.

You *must* set bit 0 if you call XOPDisplayHelpTopic from a modal dialog. This causes Igor do display a dialog containing help on top of your dialog. If you fail to set bit zero when calling XOPDisplayHelpTopic from a modal dialog, Igor may behave erratically. Unfortunately, links in help files don't work during modal help.

If you are calling XOPDisplayHelpTopic in a non-modal situation, it is appropriate to clear bit zero, but not required. If you clear bit zero, Igor displays a normal Igor help file. If you set bit zero, Igor displays a modal help dialog.

You must set all other bits to zero.

As of this writing, there is a problem in calling XOPDisplayHelpTopic from a Macintosh Cocoa XOP modal dialog running with Igor7. When the user dismisses the modal help dialog, the Cocoa XOP dialog is also dismissed. We currently have no solution for this problem.

Function result is 0 if OK or a non-zero code if the topic can not be found or some other error occurs.

Thread Safety

XOPDisplayHelpTopic is not thread-safe.

XOPSetContextualHelpMessage

```
int
XOPSetContextualHelpMessage(xopWindowRef, msg, r)
IgorWindowRef xopWindowRef;
const char* message;          // The tip.
const Rect* r;                // Hot rectangle.
```

message is a C string containing the message to display.

The function result is 0 if OK or IGOR_OBSOLETE.

Displays a message in the status bar.

On Macintosh, the status bar appears at the bottom of the command window. On Windows, it appears at the bottom of the MDI frame window.

The message is displayed until Igor is asked to display some other message, either by you via another call to XOPSetContextualHelpMessage, or by another XOP, or by an internal Igor routine.

The parameter r is ignored and can be NULL.

Thread Safety

XOPSetContextualHelpMessage is not thread-safe.

WinInfo

```
int
WinInfo(index, typeMask, name, winPtr)
int index;                    // Index number of window
int typeMask;                 // Code for type of window of interest
char name[MAX_OBJ_NAME+1];    // C string to receive name
IgorWindowRef* windowRefPtr;  // Pointer to IgorWindowRef
```

Returns information about an Igor target window (graph, table, layout, notebook or control panel).

index and typeMask are inputs.

name and windowRefPtr and the function result are outputs.

index is an index starting from 0 for the top window, 1 for the next window and so on.

typeMask is a combination of GRAF_MASK , SS_MASK, PL_MASK, MW_MASK and PANEL_MASK for graphs, tables, page layouts, notebooks and control panels. Window types and type masks are defined in IgorXOP.h.

WinInfo returns the Igor window type of the specified window or 0 if no such window exists. If 0 is returned then the name and *windowRefPtr are undefined.

Thread Safety

WinInfo is not thread-safe.

SaveXOPPrefsHandle

```
int
SaveXOPPrefsHandle(prefsHandle)
Handle prefsHandle;        // Handle containing prefs data.
```

Saves the handle in Igor's preferences file. You can retrieve the handle using **GetXOPPrefsHandle**.

Igor makes a copy of the data in the handle, so the handle is still yours after you call this. Keep or dispose of it as you wish.

If you pass NULL for the prefsHandle parameter, Igor removes any existing XOP preferences from the Igor preferences file.

Igor uses the name of your XOP's file to distinguish your preferences from the preferences of other XOPs.

Each time you call this routine, the Igor preferences file is opened and closed. Therefore, it is best to call each of it only once. One way to do this is to call GetXOPPrefsHandle when your XOPs starts and SaveX-OPPrefsHandle when you receive the CLEANUP message.

The function result is 0 if OK or a non-zero error code.

As of this writing, XOP preference handles are stored in the Igor preferences file but this may change in the future.

Thread Safety

SaveXOPPrefsHandle is not thread-safe.

GetXOPPrefsHandle

```
int
GetXOPPrefsHandle(Handle* prefsHandlePtr)
Handle* prefsHandlePtr;
```

Retrieves your XOP's preference handle from the Igor preferences file, if you have previously stored it there using **SaveXOPPrefsHandle**. In this case, on return, *prefsHandlePtr will be your preferences handle and the function result will be 0. This handle is allocated by Igor but belongs to you to keep or dispose as you wish.

If the Igor preferences file does not contain your preferences, on return, *prefsHandlePtr will be NULL and the function result will be 0.

Igor uses the name of your XOP's file to distinguish your preferences from the preferences of other XOPs.

Each time you call this routine, the Igor preferences file is opened and closed. Therefore, it is best to call each of it only once. One way to do this is to call GetXOPPrefsHandle when your XOPs starts and SaveXOPPrefsHandle when you receive the CLEANUP message.

The function result is 0 if OK or a non-zero error code.

If the result is zero and *prefHandlePtr is not NULL then *prefsHandlePtr contains a handle to your preferences.

If the result is zero and *prefHandlePtr is NULL then there was no preferences data for your XOP. You should use default settings.

If the result is non-zero then an error occurred while trying to access preferences. *prefHandlePtr will be NULL and you should use default settings.

As of this writing, XOP preference handles are stored in the Igor preferences file but this may change in the future.

Thread Safety

GetXOPPrefsHandle is not thread-safe.

GetPrefsState

```
int
GetPrefsState(prefsStatePtr)
int* prefsStatePtr;        // Receives preferences state flag.
```

Returns via bit 0 of prefsStatePtr the truth that preferences are on. Other bits are reserved for future use.

See the Igor Pro manual for information about the preferences on/off state.

The function result is 0 if OK or an error code.

Thread Safety

GetPrefsState is not thread-safe.

Programming Utilities

MemClear

```
int
MemClear(void *p, numBytes)
void* p;                    // Pointer to memory to be cleared.
BCInt numBytes;             // Number of bytes to be cleared.
```

Sets the specified number of bytes at the memory location pointed to by p to zero.

Thread Safety

MemClear is thread-safe. It can be called from any thread.

GetCStringFromHandle

```
int
GetCStringFromHandle(h, str, maxChars)
Handle h;                   // Handle containing text
char* str;                  // Output C string goes here
int maxChars;               // Max number of characters before null
```

h is a handle containing a string.

str is a null-terminated C string.

maxChars is the maximum number of bytes that str can hold, excluding the null terminator byte.

GetCStringFromHandle transfers the characters from h to str and null-terminates str.

If h is NULL, GetCStringFromHandle returns USING_NULL_STRVAR. This is typically a programmer error.

If the characters in h will not fit in str, GetCStringFromHandle returns STR_TOO_LONG.

If the characters fit, it returns 0.

For a discussion of C strings versus text handles, see **Understand the Difference Between a String in a Handle and a C String** on page 221.

Thread Safety

GetCStringFromHandle is thread-safe. It can be called from any thread.

PutCStringInHandle

```
int
PutCStringInHandle(str, h)
const char* str;            // Input C string
Handle h;                   // Handle to hold text
```

str is a null-terminated C string.

h is a handle in which the C string data is to be stored.

PutCStringInHandle transfers the characters from str to h. Note that the trailing null from the C string is not stored in the handle.

If h is NULL, it returns USING_NULL_STRVAR. This is typically a programmer error.

If an out-of-memory occurs when resizing the handle, it returns NOMEM. If the operation succeeds, it returns 0.

For a discussion of C strings versus text handles, see **Understand the Difference Between a String in a Handle and a C String** on page 221.

Thread Safety

PutCStringInHandle is thread-safe. It can be called from any thread.

CmpStr

```
int
CmpStr(char *str1, char *str2)
char* str1;                // C string
char* str2;                // C string
```

Does case-insensitive comparison.

Returns 0 if the strings are the same except for case. Returns -1 if str1 is alphabetically before str2 or 1 if str1 is alphabetically after str2.

Thread Safety

CmpStr is thread-safe. It can be called from any thread.

strchr2

```
int
strchr2(const char* str, int ch)
const char* str;           // C string to be searched
int ch;                    // Single-byte character to search for
```

strchr2 is like the standard C strchr function except that it is Asian-language-aware and assumes that the system default character encoding governs the path.

It returns a pointer to the first occurrence of ch in the null-terminated string str or NULL if there is no such occurrence. ch is a single-byte character.

On a system that uses an Asian script system as the default script, strchr2 knows about two-byte characters. For example, if you are searching for a backslash in a full path and if the path contains Asian characters, and if the second byte of an Asian character has the same code as the backslash character, strchr will mistakenly find this second byte while strchr2 will not.

On a system that does not use an Asian script system as the default script, strchr2 is just like strchr.

Thread Safety

strchr2 is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

strrchr2

```
int
strrchr2(const char* str, int ch)
const char* str;           // C string to be searched
int ch;                    // Single-byte character to search for
```

strrchr2 is like the standard C strrchr function except that it is Asian-language-aware and assumes that the system default character encoding governs the path.

Returns a pointer to the last occurrence of ch in the null-terminated string str or NULL if there is no such occurrence. ch is a single-byte character.

On a system that uses an Asian script system as the default script, strrchr2 knows about two-byte characters. For example, if you are searching for a backslash in a full path and if the path contains Asian characters, and if the second byte of an Asian character has the same code as the backslash character, strrchr will mistakenly find this second byte while strrchr2 will not.

On a system that does not use an Asian script system as the default script, strrchr2 is just like strrchr.

Thread Safety

strrchr2 is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

EscapeSpecialCharacters

```
int
EscapeSpecialCharacters(input, inputLength, output, bufSize, numCharsOutPtr)
const char* input;          // Text to be escaped
int inputLength;            // Number of characters to escape
char* buffer;               // Output buffer
int bufSize;                // Size of output buffer in characters
int* numCharsOutPtr;        // Output: Number of characters written
```

Converts CR, LF, tab, double-quote and backslash to escape sequences. This is used mostly when you are generating a command to be executed on Igor's command line via **XOPCommand**, **XOPCommand2**, **XOPCommand3** or **XOPSilentCommand** or through Igor’s Execute operation. Conversion is necessary because Igor interprets backslash as an escape character.

For example, if you are generating a file loading command and the file uses a Windows UNC path of the form \\server\share, the backslashes in the command must be escaped to give \\\\server\\share because Igor interprets \\ as an escape sequence that evaluates to a single backslash.

input is a pointer to a string to be escaped. Input may be null-terminated or not.

inputLength is the number of characters to be escaped.

NOTE: If input is null-terminated and you want output to also be null-terminated, then inputLength must include the null terminator character.

output is a pointer to a buffer in which escaped output text is returned.

outputBufferSize is the total size of the output buffer.

numCharsOutPtr is set to the number of characters stored in output. This includes the null-terminator if it was included in inputLength.

input and output can point to the same memory.

Returns 0 if OK or an error code.

Example

```
char str[32];
int length;
// Assume str is set to contain a C string containing characters
// that may need to be escaped.
length = strlen(str) + 1;     // Include null-terminator
err = EscapeSpecialCharacters(str, length, str, sizeof(str), &length);
```

Thread Safety

EscapeSpecialCharacters is thread-safe. It can be called from any thread.

UnEscapeSpecialCharacters

```
int
UnEscapeSpecialCharacters(input, inputLength, output, outputBufferSize,
numCharsOutPtr)
const char* input;          // Text to be unescaped
int inputLength;            // Number of characters to unescaped
char* buffer;               // Output buffer
int outputBufferSize;       // Size of output buffer in characters
int* numCharsOutPtr;        // Output: Number of characters written
```

Converts escape sequences for CR, LF, tab, double-quote and backslash to CR, LF, tab, double-quote and backslash. You would call this if you receive text that you know is escaped. See **EscapeSpecialCharacters** for a discussion of why text might be escaped.

input is a pointer to a string to be unescaped. Input may be null-terminated or not.

inputLength is the number of characters to be unescaped.

NOTE: If input is null-terminated and you want output to also be null-terminated, then inputLength must include the null terminator character.

output is a pointer to a buffer in which unescaped output text is returned.

outputBufferSize is the total size of the output buffer.

numCharsOutPtr is set to the number of characters stored in output. This includes the null-terminator if it was included in inputLength.

input and output can point to the same memory.

Returns 0 if OK or an error code.

Example

```
char str[32];
int length;
// Assume str is set to contain a C string containing escape sequences.
length = strlen(str) + 1;  // Include null-terminator
err = UnEscapeSpecialCharacters(str, length, str, sizeof(str), &length);
```

Thread Safety

UnEscapeSpecialCharacters is thread-safe. It can be called from any thread.

ConvertTextEncoding

```
int
ConvertTextEncoding(source, numSourceBytes, sourceTextEncoding, dest,
destBufSizeInBytes, destTextEncoding, errorMode, numOutputBytesPtr, options)
const char* source;                                // Text to be converted
int numSourceBytes;                                // Number of bytes in source text
WMTextEncodingCode sourceTextEncoding;             // Defined in IgorXOP.h
char* dest;                                        // Output buffer
int destBufSizeInBytes;                            // Size of output buffer
WMTextEncodingCode destTextEncoding;               // Defined in IgorXOP.h
WMTextEncodingConversionErrorMode errorMode; // Defined in IgorXOP.h
WMTextEncodingConversionOptions options;     // Bitwise options
int* numOutputBytesPtr;                            // Number of output bytes written
```

Converts text from one text encoding to another.

See **Text Encodings** on page 185 for background information about text encodings and how they are handled in Igor.

This routine uses ints for numSourceBytes and destBufSizeInBytes and thus the input text and the output buffer size must not exceed roughly 2 billion bytes.

source points to the input text for the conversion.

numSourceBytes is the number of bytes of source text.

sourceTextEncoding is a value of type WMTextEncodingCode - an enum defined in IgorXOP.h.

dest is the output buffer where converted data is stored. dest and source must not point to the same memory.

destBufSizeInBytes is the size of the output buffer in bytes. The number of bytes required depends on sourceTextEncoding and destTextEncoding. If destTextEncoding is kWMTextEncodingUTF8 then the output buffer, in the worst case, needs to be 6*numSourceBytes if errorMode is kWMTextEncodingConversionErrorModeEscape or 4*numSourceBytes otherwise. This is because a single input character requires, in the worst case, up to 4 bytes in UTF-8. Also if errorMode is kWMTextEncodingConversionErrorModeEscape then the conversion will replace an unmappable input character with an escape sequence consisting of up to 6 bytes. The simplest solution is to always allocate an output buffer of size 6*numSourceBytes. If you are converting very large chunks of source text you should use a smaller output buffer size chosen based on sourceTextEncoding and destTextEncoding.

destTextEncoding is a value of type WMTextEncodingCode - an enum defined in IgorXOP.h.

errorMode is a value defined by the WMTextEncodingConversionErrorMode type - an enum defined in IgorXOP.h. errorMode determines what happens if the source text can not be mapped to text in the text encoding specified by destTextEncoding. See the WMTextEncodingConversionErrorMode definition for details. For most purposes you should pass kWMTextEncodingConversionErrorModeFail for errorMode. This causes ConvertTextEncoding to return an error if the source text can not be mapped to the destination text encoding.

The number of bytes in the converted output text is stored in *numOutputBytesPtr.

options is a bitwise combination of WMTextEncodingConversionOptionFlag values as defined in IgorXOP.h. Typically you should form this parameter like this:

```
WMTextEncodingConversionOptions tecOptions = kTECOptionFlagDontAllowNulls;
tecOptions |= kTECOptionFlagDoConversionEvenIfEncodingsAreTheSame;
```

kTECOptionFlagDontAllowNulls causes ConvertTextEncoding to return an error if the input text contains nulls. Normally you don't want nulls in text but if for some reason you do, pass kTECOptionFlagAllowNulls instead of kTECOptionFlagDontAllowNulls.

kTECOptionFlagDoConversionEvenIfEncodingsAreTheSame forces ConvertTextEncoding to do the conversion even if sourceTextEncoding and destTextEncoding are the same. This is useful to validate that the source text is in fact valid text in the specified source text encoding.

If you know that the source text is valid, you can omit kTECOptionFlagDoConversionEvenIfEncodingsAreTheSame. In this case, if sourceTextEncoding and destTextEncoding are the same, ConvertTextEncoding merely copies the source text to the destination buffer without doing any validation.

The function result is 0 if OK or a non-zero error code.

Thread Safety

ConvertTextEncoding is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself.

IsINF32

```
int
IsINF32(floatPtr)
float* floatPtr;            // The number to test
```

Returns 1 if the number pointed to by floatPtr is +infinity or –infinity, 0 otherwise.

Thread Safety

IsINF32 is thread-safe. It can be called from any thread.

IsINF64

```
int
IsINF64(doublePtr)
double* doublePtr;          // The number to test
```

Returns 1 if the number pointed to by doublePtr is +infinity or –infinity, 0 otherwise.

Thread Safety

IsINF64 is thread-safe. It can be called from any thread.

IsNaN32

```
int
IsNaN32(floatPtr)
float* floatPtr;            // The number to test
```

Returns 1 if the number pointed to by floatPtr is a NaN (not-a-number) or 0 otherwise.

Thread Safety

IsNaN32 is thread-safe. It can be called from any thread.

IsNaN64

```
int
IsNaN64(doublePtr)
double* doublePtr;          // The number to test
```

Returns 1 if the number pointed to by doublePtr is a NaN (not-a-number) or 0 otherwise.

Thread Safety

IsNaN64 is thread-safe. It can be called from any thread.

SetNaN32

```
void
SetNaN32(floatPtr)
float* floatPtr;
```

Sets the float pointed to by the parameter to NaN (not-a-number).

Thread Safety

SetNaN32 is thread-safe. It can be called from any thread.

SetNaN64

```
void
SetNaN64(doublePtr)
double* doublePtr;
```

Sets the double pointed to by the parameter to NaN (not-a-number).

Thread Safety

SetNaN64 is thread-safe. It can be called from any thread.

TickCount

```
TickCountInt
TickCount(void)
```

TickCount returns a count of the number of ticks that have elapsed since Igor started up.

A tick is approximately one sixtieth of a second. TickCount is a simple way to determine the amount of time that has elapsed from one point in the program to another.

Thread Safety

TickCount is thread-safe. It can be called from any thread.

DateToIgorDateInSeconds

```
int
DateToIgorDateInSeconds(numValues, year, month, dayOfMonth, secs)
int numValues;           // Number of dates to convert
short* year;             // e.g., 2004
short* month;            // 1=January, 2=February, . . .
short* dayOfMonth;
double* secs;            // Output in Igor date format
```

Converts dates into Igor date format (seconds since 1/1/1904).

numValues is the number of dates to convert.

year, month and dayOfMonth and secs are arrays allocated by the calling routine. The size of each array is specified by numValues.

On input, year, month and dayOfMonth hold the input values. On return, secs holds the output values.

The function result is zero or an error code.

Thread Safety

DateToIgorDateInSeconds is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

IgorDateInSecondsToDate

```
int
IgorDateInSecondsToDate(numValues, secs, dates)
int numValues;           // Number of dates to convert
double* secs;            // Input in Igor date format
short* dates;            // Output goes here
```

Converts dates in Igor date format (seconds since 1/1/1904) into date records.

numValues is the number of Igor dates to convert.

secs is an array of dates in Igor date format. Its size is specified by numValues.

dates is an array of shorts. It must hold 7*numValues shorts. For each input value, 7 values are written to the dates array, in the following order:

```
year, month, dayOfMonth, hour, minute, second, dayOfWeek
```

The function result is zero or an error code.

For example:

```
double secs[2];
short dates[2*7];
int err;
```

```
   secs[0] = 0;         // Represents January 1, 1904, midnight.
   secs[1] = 24*60*60;  // Represents January 2, 1904, midnight.
   err = IgorDateInSecondsToDate(2, secs, dates);
```

Thread Safety

IgorDateInSecondsToDate is Igor-thread-safe. You can call it from a thread created by Igor but not from a private thread that you created yourself. See **Igor-Thread-Safe Callbacks** on page 162 for details.

XOPBeep

```
void
XOPBeep(void)
```

Emits a beep.

Thread Safety

XOPBeep is not thread-safe.

XOPOKAlert

```
void
XOPOKAlert(title, message)
const char* title;         // Dialog title.
const char* message;       // Message to be displayed.
```

Displays an alert (also known as "message box") and waits for the user to click OK.

Thread Safety

XOPOKAlert is not thread-safe.

XOPOKCancelAlert

```
int
XOPOKCancelAlert(title, message)
const char* title;         // Dialog title.
const char* message;       // Message to be displayed.
```

Displays an alert (also known as "message box") and waits for the user to click OK or Cancel.

Returns 1 for OK, -1 for cancel.

Thread Safety

XOPOKCancelAlert is not thread-safe.

XOPYesNoAlert

```
int
XOPYesNoAlert(title, message)
const char* title;         // Dialog title.
const char* message;       // Message to be displayed.
```

Displays an alert (also known as "message box") and waits for the user to click Yes or No.

Returns 1 for yes, 2 for no.

Thread Safety

XOPYesNoAlert is not thread-safe.

XOPYesNoCancelAlert

```
int
XOPYesNoCancelAlert(title, message)
const char* title;          // Dialog title.
const char* message;        // Message to be displayed.
```

Displays an alert (also known as "message box") and waits for the user to click Yes or No or Cancel.

Returns 1 for yes, 2 for no, -1 for cancel.

Thread Safety

XOPYesNoCancelAlert is not thread-safe.

MacRectToWinRect

```
void
MacRectToWinRect(mr, wr)
const Rect* mr;             // Macintosh rectangle
RECT* wr;                   // Windows rectangle
```

Igor sometimes passes a Macintosh rectangle to your XOP as a message argument. Use MacRectToWin-Rect when you receive a Macintosh rectangle but you need a Windows rectangle.

Thread Safety

MacRectToWinRect is thread-safe. It can be called from any thread.

WinRectToMacRect

```
void
WinRectToMacRect(wr, mr)
const RECT* wr;             // Windows rectangle
Rect* mr;                   // Macintosh rectangle
```

Some XOPSupport routines take a Macintosh rectangle as a parameter. Use WinRectToMacRect when an XOPSupport routine requires a Macintosh rectangle but you have a Windows rectangle.

Thread Safety

WinRectToMacRect is thread-safe. It can be called from any thread.

XOPGetClipboardData

```
int
XOPGetClipboardData(dataType, options, hPtr, lengthPtr)
OSType dataType;
int options;
Handle* hPtr;
BCInt* lengthPtr;
```

XOPGetClipboardData returns data from the clipboard in a handle via hPtr.

It returns the length of the data via lengthPtr.

dataType indicates the type of data you want to receive. The following values are supported:

'TEXT'	'UTF-8 text
'DIB '	'Windows only. The last character is a space.
'EMF '	'Windows only. The last character is a space.
'JPEG'	

'PDF '	The last character is a space.
'PNGf'	
'SVG '	The last character is a space.
'TIFF'	

options is for possible future use. Pass 0.

The output data is returned via hPtr. In the event of an error, *hPtr is set to NULL.

If *hPtr is not NULL then it belongs to you and you must dispose it via WMDisposeHandle.

The length of the output data is returned via lengthPtr. This will be the same as WMGetHandleSize(*hPtr);

If you just want to tell if a given type of data is available on the clipboard and don't want to actually get that data, pass NULL for hPtr. In this case, XOPGetClipboardData sets *lengthPtr to the length of the data of the specified type or to zero if there is no such data.

XOPGetClipboardData returns 0 in the event of success or a non-zero Igor error code.

Thread Safety

XOPGetClipboardData is not thread-safe.

XOPSetClipboardData

```
int
XOPGetClipboardData(dataType, options, data, length)
OSType dataType;
int options;
void* data;
BCInt length;
```

XOPSetClipboardData stores data in the clipboard.

dataType indicates the type of data you are storing. The following values are supported:

'TEXT'	'UTF-8 text
'DIB '	'Windows only. The last character is a space.
'EMF '	'Windows only. The last character is a space.
'JPEG'	
'PDF '	The last character is a space.
'PNGf'	
'SVG '	The last character is a space.
'TIFF'	

options is a bitwise parameter defined as follows:

Bit	Meaning
Bit 0	If cleared, XOPSetClipboardData clears the clipboard before storing data. If set, it does not clear the clipboard.
All other bits	Reserved for future use and must be cleared.

In most cases, you should pass 0 for options. This causes XOPSetClipboardData to clear the clipboard and then store your data in it. If bit 0 is set, XOPSetClipboardData does not clear the clipboard and you may wind up with multiple types of data in the clipboard.

data points to the data to be stored in the clipboard.

length is the number of bytes to be stored in the clipboard.

XOPSetClipboardData returns 0 in the event of success or a non-zero Igor error code.

On Windows, setting the clipboard via multiple successive calls can cause errors because programs that monitor the clipboard open it to inspect its contents each time it is changed. This causes Windows to return an error when Igor tries to open the clipboard. Repeatedly calling XOPSetClipboardData to store multiple formats on the clipboard may trigger this problem on some systems on some systems and is not recommended.

Thread Safety

XOPSetClipboardData is not thread-safe.

WM Memory Routines

The WM memory XOPSupport routines provide a mechanism by which Igor and XOPs can exchange data in a compatible way.

WM memory XOPSupport routines use two data types, Ptr and Handle. They both provide access to a block of memory allocated in the heap. Ptr is rarely used while Handle is commonly used, most often for holding variable-length string data.

See **WM Memory XOPSupport Routines** on page 179 for background information.

WMNewHandle

```
Handle
WMNewHandle(size)
BCInt size;
```

WMNewHandle allocates a block of size bytes in the heap and returns a reference to that block.

In the event of an error, WMNewHandle returns NULL. This corresponds to a NOMEM error. For example:

```
Handle h;
h = WMNewHandle(100);
if (h == NULL)
   return NOMEM;
```

You must call **WMDisposeHandle** to free the block of memory allocated by WMNewHandle

Thread Safety

WMNewHandle is thread-safe. It can be called from any thread.

WMGetHandleSize

```
BCInt
WMGetHandleSize(h)
Handle h;
```

h is a handle referencing a block of memory in the heap.

WMGetHandleSize returns the number of bytes in the block of memory that h references.

NOTE: In Igor Pro 7 and later wave handles are not regular handles. In the unlikely event that you need to know the size of a wave handle, use **WaveMemorySize**, not WMGetHandleSize.

Thread Safety

WMGetHandleSize is thread-safe. It can be called from any thread.

WMSetHandleSize

```
int
WMSetHandleSize(h, size)
Handle h;
BCInt size
```

h is a handle referencing a block of memory in the heap.

WMSetHandleSize resizes the block of memory that h references to the number of bytes specified by size.

After increasing the size of a handle, you must re-dereference it. See **Resizing Handles** on page 182 for details.

WMSetHandleSize returns 0 if it succeeds or a non-zero error code if it fails.

Example

```
Handle h;
Ptr p;
int err = 0;

h = WMNewHandle(100);           // Allocate handle
if (h == NULL)
   return NOMEM;
p = *h;                         // Dereference handle
. . .                           // Work with handle data using p
err = WMSetHandleSize(h, 200);// This may relocate handle data in memory
if (err != 0) {
   WMDisposeHandle(h);
   return err;
}
p = *h;                         // Re-dereference handle
. . .                           // Work with handle data using p
WMDisposeHandle(h);             // All done
```

Thread Safety

WMSetHandleSize is thread-safe. It can be called from any thread.

WMHandToHand

```
int
WMHandToHand(destHandlePtr)
Handle* destHandlePtr;
```

WMHandToHand creates a new block of memory that contains the same data as an existing block of memory.

It returns 0 if the allocation succeded or an error code.

In this example, we assume that h1 is an existing handle to a block of memory.

```
Handle h2;
int err;
h2 = h1;            // h2 now refers to the same block of memory as h1.
if (err = WMHandToHand(&h2))
   return err;
<Use h2>            // h2 now refers to a new block of memory.
WMDisposeHandle(h2);
```

Thread Safety

WMHandToHand is thread-safe. It can be called from any thread.

WMHandAndHand

```
int
WMHandAndHand(h1, h2)
Handle h1;
Handle h2;
```

h1 and h2 are handles created by **WMNewHandle**.

WMHandAndHand appends the contents of the block of memory referenced by h1 to the block of memory referenced by h2. In the process, it resizes the block referenced by h2.

It returns 0 if the allocation succeded or an error code.

Thread Safety

WMHandAndHand is thread-safe. It can be called from any thread.

WMDisposeHandle

```
void
WMDisposeHandle(h)
Handle h;
```

h is a handle referencing a block of memory in the heap.

WMDisposeHandle frees the block of memory that h references. After calling WMDisposeHandle, h is no longer a valid reference.

Thread Safety

WMDisposeHandle is thread-safe. It can be called from any thread.

WMNewPtr

```
Ptr
WMNewPtr(size)
BCInt size;
```

WMNewPtr allocates a block of size bytes in the heap and returns a pointer to that block.

In the event of an error, WMNewPtr returns NULL. This corresponds to a NOMEM error. For example:

```
Ptr p;
p = (Ptr)WMNewPtr(100);
if (p == NULL)
   return NOMEM;
```

You must call **WMDisposePtr** to free the block of memory allocated by WMNewPtr.

Thread Safety

WMNewPtr is thread-safe. It can be called from any thread.

WMGetPtrSize

```
BCInt
WMGetPtrSize(p)
Ptr p;
```

p is a pointer to a block of memory allocated by **WMNewPtr**.

WMGetPtrSize returns the size in bytes of that block of memory.

Thread Safety

WMGetPtrSize is thread-safe. It can be called from any thread.

WMSetPtrSize

```
int
WMSetPtrSize(p, size)
Ptr p;
BCInt size;
```

p is a pointer to a block of memory allocated by **WMNewPtr**.

WMSetPtrSize resizes the block to the number of bytes specified by the size parameter.

WMSetPtrSize returns 0 if it succeeds or a non-zero error code if it fails.

Thread Safety

WMSetPtrSize is thread-safe.

WMPtrToHand

```
int
WMPtrToHand(srcPtr, destHandlePtr, size)
Ptr srcPtr;
Handle* destHandlePtr;
BCInt size;
```

WMPtrToHand allocates a new block of memory in the heap and then copies size bytes from srcPtr to the new block. It returns a handle referencing the new block via destHandlePtr.

It returns 0 if the allocation succeded or an error code.

Thread Safety

WMPtrToHand is thread-safe. It can be called from any thread.

WMPtrAndHand

```
int
WMPtrAndHand(p, h, size)
Ptr* p;
Handle h;
BCInt size;
```

h is a handle referencing a block of memory in the heap.

WMPtrAndHand resizes the block and then appends size bytes of data to the block by copying from the pointer p.

After increasing the size of a handle you must re-dereference it. See **Resizing Handles** on page 182 for details.

WMPtrAndHand returns 0 if the allocation succeded or an error code.

Thread Safety

WMPtrAndHand is thread-safe. It can be called from any thread.

WMDisposePtr

```
void
WMDisposePtr(p)
Ptr p;
```

p is a pointer to a block of memory allocated by **WMNewPtr**.

WMDisposePtr frees the block of memory. After calling WMDisposePtr, you must not access the memory.

Thread Safety

WMDisposePtr is thread-safe. It can be called from any thread.

XOP Toolkit 8 Upgrade Notes

Overview

These notes are for XOP programmers transitioning from XOP Toolkit 7 to XOP Toolkit 8.

Changes from XOP Toolkit 7 to XOP Toolkit 8 are relatively minor.

Changes from XOP Toolkit 6 to XOP Toolkit 7 were major. *If you are transitioning from XOP Toolkit 6, we recommend that you first update your XOP using XOP Toolkit 7 before updating with XOP Toolkit 8.* See **Choosing Which XOP Toolkit to Use** on page 5 for details. See Appendix A in the XOP Toolkit 7 manual for instructions. Alternatively you can create a new XOP Toolkit 8 project and import your source code into it - see **Alternate Method for Updating a Very Old XOP** on page 404.

Here are the main new aspects of XOP Toolkit 8:

- XOP Toolkit 8 supports development of XOPs that require Igor Pro 8.00 or later
- Long object names and paths are supported
- Pass-by-reference wave and DFREF parameters are supported
- The CallFunction callback supports calling user-defined functions that use multiple return syntax

These and other changes are explained below in this chapter.

If you are updating an existing XOP Toolkit 7 XOP, please familiarize yourself with the entirety of this appendix. Most of the changes will not affect you but you should know what they are just in case.

Development Systems Supported by XOP Toolkit 8

XOP Toolkit 8 provides support and samples for creating XOPs using these development systems:

For MacOS XOPs:	Apple's Xcode 11 or later
For Windows XOPs:	Microsoft's Visual C++ 2015, 2017 and 2019

Newer development systems will likely be able to open these projects without problems.

Create a Copy of Your Existing XOPs

The support and sample files for XOP Toolkit 8 come in a folder named IgorXOPs8.

If you have existing XOP projects, *copy* them into the IgorXOPs8 folder. Leave your old projects as they are and do all new development in the new folder.

Changes You Must Make

This section assumes that your XOP was updated for XOP Toolkit 7. If not, we recommend that you first update your XOP using XOP Toolkit 7 before updating with XOP Toolkit 8. See **Choosing Which XOP Toolkit to Use** on page 5 for details.

If you have XOPs developed with XOP Toolkit 7, here are the changes that you must make in order to use XOP Toolkit 8. We recommend that you familiarize yourself with this entire appendix first and then come back to this section and perform each of these steps.

XOPs created with XOP Toolkit 8 require Igor Pro 8.00 or later. Make sure that your XOPMain function checks the version of Igor it is running with. See **Checking the Igor Version** on page 397 for details.

Update your XOP project using instructions under **Xcode Project Changes For XOP Toolkit 8** on page 399 or **Visual C++ Project Changes For XOP Toolkit 8** on page 403.

For the most part, you just need to recompile your XOP using XOP Toolkit 8 to support long names and paths. In some cases, you may need to tweak your source code. See **Long Names and Paths in XOPs** on page 189.

Build and test your XOP with XOP Toolkit 8. Examine all compiler warnings and determine if they are harmless or indicate a real problem. Eliminate compiler warnings where possible.

New Features

Igor Pro 8.00 increased the maximum size of an object name from 31 to 255 bytes. It also increased the maximum size of file paths to 2000 bytes and of commands and data folder paths to 2500 bytes. For details, see **Long Names and Paths in XOPs** on page 189.

XOP Toolkit 8 supports external functions with pass-by-reference wave reference and pass-by-reference data folder reference parameters. See **Pass-By-Reference Parameters** on page 112 for details.

The CheckFunctionForm and CallFunction callbacks support calling user-defined functions that use multiple return syntax. See **Calling User-Defined Functions That Return Multiple Results** on page 199 for details.

You can pass -1 for the parentFolderH parameter to **NewDataFolder(parentFolderH, newDataFolderName, newDataFolderHPtr)** to create a free data folder.

XOPStandardHeaders Changes

To support long names and paths, the constants MAX_OBJ_NAME, MAX_WAVE_NAME, MAX_DIM_LABEL_BYTES, MAXCMDLEN, MAX_PATH_LEN were changed. See **Long Names and Paths in XOPs** on page 189.

Added error codes to IgorErrors.h.

Added the FV_NO_RETURN_TYPE #define to IgorXOP.h. This is used with CallFunction when calling a user-defined function that returns multiple results as described under **Calling User-Defined Functions That Return Multiple Results** on page 199.

Added the WAVEWAVE_TYPE #define to IgorXOP.h. This is used with CallFunction when calling a user-defined function that returns a WAVE/WAVE parameter as described under **Calling User-Defined Functions That Return Multiple Results** on page 199.

Added the TEXT_TYPE #define to XOPResources.h. This is used only in an XOPF resource to indicate a text wave reference parameter when declaring a pass-by-reference wave reference parameter as described under **Pass-By-Reference Wave Reference Parameters** on page 113.

Organizational Changes

None.

Removed XOPSupport Routines

No XOPSupport routines were removed from XOP Toolkit 7 to XOP Toolkit 8.

Changed XOPSupport Routines

The behavior of these routines was changed in XOP Toolkit 8 or as of Igor8:

Changed Routine	Description
NewDataFolder	The parentDataFolderH parameter can be -1 to create a free data folder.
CheckName	In Igor Pro 8.00 or later, CheckName returns an error if called from an Igor pre-emptive thread if objectType is other than WAVE_OBJECT, VAR_OBJECT, STR_OBJECT, DATAFOLDER_OBJECT, or PATH_OBJECT.
UniqueName2	In Igor Pro 8.00 or later, UniqueName2 returns an error if called from an Igor pre-emptive thread if namespaceCode is other than MAIN_NAME_SPACE, DATAFOLDERS_NAME_SPACE, or PATHS_NAME_SPACE.

New XOPSupport Routines

No XOPSupport routines were added from XOP Toolkit 7 to XOP Toolkit 8.

Checking the Igor Version

XOPs created using XOP Toolkit 8 require Igor Pro 8.00 or later. To prevent your XOP from running with earlier versions of Igor, you must put a test in your main function, like this:

```
if (igorVersion < 800) {
   SetXOPResult(IGOR_OBSOLETE);
   return EXIT_FAILURE;
}
```

IGOR_OBSOLETE is a built-in Igor error code that generates an error alert that says "XOP requires a later version of Igor".

Project Changes For XOP Toolkit 8

Overview

This appendix describes change you need to make to your Xcode and Visual C++ projects when upgrading from XOP Toolkit 7 to XOP Toolkit 8.

XOP Toolkit 8 supports development of XOPs that run with Igor Pro 8.00 or later.

If you are updating an old XOP that was never updated with XOP Toolkit 7, you should update it using XOP Toolkit 7 before proceding to XOP Toolkit 8. See **Choosing Which XOP Toolkit to Use** on page 5 for details.

An alternate approach to updating a very old XOP to XOP Toolkit 8 is to create a new XOP from a sample XOP and then replace the sample source files with your source files. See **Alternate Method for Updating a Very Old XOP** on page 404 below for details.

Update Your XOPI Resource For XOP Toolkit 8

The XOPI 1100 resource in your .r or WinCustom.rc file must be updated. See **The XOPI 1100 Resource** on page 54 for details.

Xcode Project Changes For XOP Toolkit 8

XOP Toolkit 8 works with Xcode 11 or later. It has been tested with Xcode 11, 12, and 13. To see what version of Xcode runs on what operating system, consult http://www.wikipedia.org/wiki/Xcode.

The following section walks through updating an XOP Toolkit 7 or XOP Toolkit 8 XOP for use with Xcode 12.

Updating Xcode Projects for Xcode 12

This section explains updating XOP Toolkit 7 and 8 projects for Xcode 12 compatibility.

Before starting, make a backup of your XOP projects.

In the following sections we use the XOP1 sample XOP as an example. Replace “XOP1” with the name of your XOP.

1. If you are updating from XOP Toolkit 7, copy the project folder, XOP1, from your IgorXOPs7 folder to your IgorXOPs8 folder.
2. Open your project in Xcode 12.

   If your project includes a 32-bit target, Xcode may display a dialog saying "32-bit MacOS targets are no longer supported". Click OK.

Showing the Projects and Targets List

1. In Xcode, choose View→Navigators→Project.
2. Select the top icon ("XOP1") in the Project Navigator. This displays settings in the Xcode window central pane.

You should see a pane, called the Projects and Targets list, with sections PROJECT and TARGETS to the right of the Project Navigator pane. If you don't see the Projects and Targets list, click the square icon in the top/left corner of the project settings pane.

Displaying Project and Target Build Settings

In the sections below, "Display the *project* build settings" means the following:

1. In Xcode, choose View→Navigators→Project.

   You can also click the project icon in the toolbar above the lefthand pane to display the project navigator.
2. Select the XOP1 icon in the top/left corner of the Project Navigator pane.
3. Click the XOP1 icon under PROJECT in the build settings.
4. Click the Build Settings tab if it is not already selected to display project build settings.

In the sections below, "Display the *target* build settings" means the same thing except that, in step 3, click XOP1-64 under TARGETS instead of XOP1 under PROJECT.

Displaying Project and Target Info Settings

In the sections below, "Display the *project* info settings" means the following:

1. In Xcode, choose View→Navigators→Project.

   You can also click the project icon in the toolbar above the lefthand pane to display the project navigator.
2. Select the XOP1 icon in the top/left corner of the Project Navigator pane.
3. Click the XOP1 icon under PROJECT in the build settings.
4. Click the Info tab if it is not already selected to display project info settings.

In the sections below, "Display the *target* info settings" means the same thing except that, in step 3, click XOP1-64 under TARGETS instead of XOP1 under PROJECT.

Deleting the 32-bit Target

If your XOP project has no 32-bit target, skip this section.

1. Display the project info settings.

   Select the 32-bit target ("XOP1") in the TARGETS list.

   Click the minus symbol in the bottom/left corner of the project settings pane to delete the 32-bit target.

   When prompted, click the Delete button.
2. Choose Product→Scheme→Manage Schemes.

   Select the 32-bit scheme ("XOP1") in the list.

   Click the minus symbol in the bottom/left corner of the Manage Schemes window.

   When prompted, click the Delete button.

   Click Close.
3. In the Project Navigator pane, in the Resources group, right-click the Info.plist icon and choose Delete. Do not delete Info64.plist.

When prompted, click Move to Trash.

4. In the Project Navigator pane, right-click the libXOPSupport.a icon and choose Delete.

   If prompted, click Remove Reference.

Updating to Recommended Project Settings

1. Choose View→Navigators→Issues.

   You should see an item in the Issue Navigator pane that says "Update to recommended settings". Click it. A window will open that lists settings to be updated.

2. Click Perform Changes.

Updating Localization Settings

To avoid warnings, for Xcode 12 and later, we need to change localization settings in the XOP project. Most XOPs do not need to be localized and we want to remove any unused localizations to get rid of the warnings, but we have to leave one localization intact. In the following steps, we will remove Japanese, French, and German, leaving English.

Updating the English Localization

Here are steps for updating the English localization using XOP1 as an example:

1. Display the project info settings.
2. Find the Localizations section of the Info tab.

   The English localization says “English, deprecated - Development Language”.

3. In Xcode, choose View→Navigators→Issues.
4. Click the Migrate “English.lproj” issues.

   Xcode displays a dialog offering to move “English.lproj” to “en.lproj”.

5. Click the Migrate button.

   “Deprecated” is removed from the English localization. Xcode renamed the folder English.lproj as en.lproj.

6. In the Finder, verify that there is an en.lproj folder in the project’s Xcode folder and that it contains InfoPlist.strings.
7. If there is an empty English folder in the Xcode folder, delete it.

Remove Unused Localizations

Here are steps to remove the unused localizations using XOP1 as an example:

1. Display the project info settings.
2. Find the Localizations section of the Info tab.
3. Select Japanese, if present, and press the minus icon below the list of localizations to remove Japanese.
4. Repeat step 6 for German and French.

Enabling Base Internationalization

Finally we will enable "base internationalization" which may be necessary to avoid warnings.

1. Check the Use Base Internationalization item in the Info tab of the project build settings.

   This adds a localization named “Base”.

To remove warnings for issues that we just fixed, close the Xcode project and reopen it.

Changing the Deployment Target

1. Display the project info settings.
2. Set MacOS Deployment Target to the earliest MacOS version that you want to support but it must be 10.11 or higher.
3. Click the 64-bit target ("XOP1-64") under TARGETS and then click General.
4. In the Deployment Info section, make sure that the Deployment Target is set the same as you set it for the project.

Disabling ARM

ARM is the architecture of the Apple M1 and later machines. Igor currently runs on the Intel architecture only and does not run on ARM. Starting with Xcode 12.2, Xcode attempts to build for the ARM architecture by default. This generates a build error. This section shows how to prevent the error by disabling the ARM build using XOP1 as an example.

1. Display the project build settings.

   Make sure to click the XOP1 icon under PROJECT, not the XOP1-64 icon under TARGETS.
2. Click the All and Combined buttons.

   The Architectures section should appear. You may need to scroll up to see it.
3. For the Excluded Architectures setting, enter arm64.

Changing the "Always Search User Paths" Setting

1. In the Search Paths section of the project build settings, set Always Search User Paths to No.
2. Click the 64-bit target ("XOP1-64") under TARGETS. Make sure that the Always Search User Paths is set to No.

Building the Project

Choose Project→Build. It should compile without errors though you may get warnings.

If you get an error that says "Could not decode input file using specified encoding", in the Finder, overwrite the project's InfoPlist.string file with the same-named file from an XOP Toolkit project. Then, in Xcode, replace the file's contents with "`// Localized strings go here`". Then choose Project→Build again.

If you get other errors you will need to debug them. There is no generic advise for errors at this point of the process.

Handling Warnings

You may get warnings that you did not get before. This is because the "Updating to Recommended Project Settings" step turns on additional warnings. We recommend fixing warnings unless the fix is too complicated. Most warnings can be fixed with an appropriate cast. For example, change:

```
int len = strlen(str);
```

to

```
int len = (int)strlen(str);
```

You may see an intermittent "Enable Base Internationalization" warning. We are not aware of a reliable way to get rid of this warning.

Visual C++ Project Changes For XOP Toolkit 8

XOP Toolkit 8 was created with Visual C++ 2015 and has also been tested with Visual C++ 2017 and Visual C++ 2019. It will most-likely work with later versions of Visual C++. If you must use an earlier version, see **Visual C++ Compatibility Issues** on page 45.

Converting Your Older Visual C++ Project

In this section we show how to update a Visual C++ project from XOP Toolkit 7 to a Visual C++ 2019 project for use with XOP Toolkit 8. The instructions should also work for Visual C++ 2015 and Visual C++ 2017.

If you are updating an old XOP that was never updated with XOP Toolkit 7, you should update it using XOP Toolkit 7 before proceding to XOP Toolkit 8. See **Choosing Which XOP Toolkit to Use** on page 5 for details.

We use XOP1 as an example. The XOP1 project that we are starting with is from XOP Toolkit 7.01. To convert your project, substitute its name for “XOP1” in the following instructions.

1. If you have not already done it, copy the project folder, XOP1, from your IgorXOPs7 folder to your IgorXOPs8 folder.

   All of the steps below are to be done on the copy in IgorXOPs8.
2. Open XOP1/VC/XOP1.sln in Visual C++ 2019 (or 2015 or 2017).

   Visual C++ may display a dialog asking if you want to use the latest platform toolset such as “v142” (for Visual C++ 2019). Click OK to upgrade the platform toolset.

Updating the 32-bit Visual C++ Target

1. Choose View→Solution Explorer.
2. Right-click the XOP1 icon and choose Properties to display the XOP1 Property Pages dialog.

   From the Configuration popup menu, choose All Configurations.

   From the Platform popup menu, choose Win32.
3. Under Configuration Properties, select Debugging and enter the following setting:

   Command: <path to your Igor.exe application for Igor Pro 8 or later>

   For example: C:\Program Files\WaveMetrics\Igor Pro 9 Folder\IgorBinaries_Win32\Igor.exe

   Click Apply.
4. Click OK to close the Property Pages dialog.
5. Choose File→Save All.
6. From the Configuration popup menu, choose Debug.
7. Choose Build→Build Solution.

   The project should successfully compile and link, producing XOP1.xop. You may get some warnings.

   To start the debugger, choose Debug→Run or press F5.

Updating the 64-bit Visual C++ Target

1. Choose View→Solution Explorer.
2. Right-click the XOP1 icon and choose Properties to display the XOP1 Property Pages dialog.

   From the Configuration popup menu, choose All Configurations.

   From the Platform popup menu, choose x64.
3. Under Configuration Properties, select Debugging and enter the following setting:

   Command: <path to your Igor64.exe application for Igor Pro 8 or later>

   For example: C:\Program Files\WaveMetrics\Igor Pro 9 Folder\IgorBinaries_x64\Igor64.exe

Click Apply.

4. Click OK to close the Property Pages dialog.
5. Choose File→Save All.
6. From the Configuration popup menu, choose Debug.
7. Choose Build→Build Solution.

   The project should successfully compile and link, producing XOP1-64.xop. You may get some warnings.

   To start the debugger, choose Debug→Run or press F5.

Text Encoding Issues

In XOP Toolkit 8, we use UTF-8 text encoding for all C and C++ source files. This matters only if your XOP uses non-ASCII literal strings. See **Text Encodings** on page 185 for details.

Alternate Method for Updating a Very Old XOP

The preceding sections provide instructions for updating an XOP Toolkit 7 XOP for use with XOP Toolkit 8 and with recent versions of Xcode and Visual C++. This section provides an alternative method which is easier for porting very old XOPs.

1. Create a new XOP project as explained under **Creating a New Project** on page 24.
2. Remove the source files from the new XOP project.
3. Add your source files to the new XOP project.
4. Copy the XOPI resource from the .r or WinCustom.rc file of a sample XOP and replace the XOPI resource in your new XOP project with the copied resource.
5. Copy the XOPMain function from the main source file (e.g., XOP1.cpp) of a sample XOP, paste it into your main source file, add anything from your old XOPMain or main function to the new function, and then delete your old XOPMain or main function.
6. Copy the XOPMain declaration from the main header file (e.g., XOP1.h) of a sample XOP, paste it into your main header file, replacing your old XOPMain or main declaration.
7. Add any libraries that you need to the new XOP project.
8. Build the new XOP project.
9. Fix any resulting errors.

If you get errors, see **Development Systems** on page 35 which discusses the settings that are most-likely to need changing for your new XOP project.

XOP Toolkit 8 Release History

Overview

This appendix describes changes in each new release of XOP Toolkit 8.

XOP Toolkit 8 supports development of XOPs that run with Igor Pro 8.00 or later.

If you are updating an old XOP that was never updated with XOP Toolkit 7, you should update it using XOP Toolkit 7 before proceding to XOP Toolkit 8. See **Choosing Which XOP Toolkit to Use** on page 5 for details.

For a discussion of what is new in XOP Toolkit 8 relative to XOP Toolkit 7, see **XOP Toolkit 8 Upgrade Notes** on page 395.

Release 8.00

June 4, 2018

First release of XOP Toolkit 8.

Release 8.01

September 28, 2018

XOP Toolkit 8.01 adds Xcode 10 compatibility. Xcode 10 supports 64-bit development only and requires MacOS 10.13.6 or later.

The 32-bit targets in the Xcode project files were removed. They are not needed because there is no 32-bit MacOS version of Igor Pro 8 and XOPs created by XOP Toolkit 8 require Igor Pro 8 or later.

For instructions on updating XOP Toolkit 7 and 8 XOPs for Xcode, see **Xcode Project Changes For XOP Toolkit 8** on page 399.

Release 8.02

October 27, 2021

In XOP Toolkit 7, we added UTF-8 byte-order marks (BOMs) to all of the C/C++ source files shipped with the XOP Toolkit. This had no effect in Xcode but guaranteed that Visual Studio would recognize the files as UTF-8. However, whereas Visual Studio preserves the UTF-8 BOM when you edit a file, Xcode removes it. Consequently some of the source files shipped with the XOP Toolkit lost their BOMs. For XOP Toolkit 8.02, we decided to remove the BOMs altogether.

Documented the fact that **GetDataFolderIDNumber** and **GetDataFolderByIDNumber** work for data folders in the main thread’s data hierarchy only, not for free root data folders and their descendants or for preemptive thread root data folders and their descendants.

Made the VDT2 XOP external operations threadsafe so they can be used from a pre-emptive thread. Thanks to Michael Huth of **byte-physics** for contributing the code for this feature.

Added /P=portName flag to all VDT2 operations. Thanks to Michael Huth of **byte-physics** for contributing the code for this feature.

Changed XOPEmergencyAlert on Macintosh to call XOPNotice instead of displaying an alert when called from a pre-emptive thread because the Cocoa NSAlert crashes in a pre-emptive thread.

Added XOP1.ihf, help file for the XOP1 sample project.

In “NIGPIB2 Self Tests.pxp”, procedure file "Interpreted", line 127: Removed /C from Duplicate command.

Updated IgorErrors.h to include Igor Pro 9.00 errors.

Macintosh: Disabled building of arm64 architecture in sample XOPs using Excluded Architectures setting added in Xcode 12.2

Macintosh: Fixed localization-related warnings in sample XOPs that appear in Xcode 12 and 13.

Macintosh: Enabled base localization in sample XOPs as recommended in Xcode 12 and 13.

Macintosh: Fixed incorrect bundle identifier in VDTDialogConroller.mm.

Macintosh: Successfully tested sample XOPs with Xcode 12.5.

Windows: Successfully tested sample XOPs with Visual C++ 2019.

Added section **Updating Xcode Projects for Xcode 12** on page 399 and removed similar sections for Xcode 9 and Xcode 10.

Chapter 9, **Adding Windows**, was replaced with a brief explanation that adding windows is no longer supported.

Added a mention of signing and notarization in Xcode - see **Signing and Notarizing an XOP in Xcode** on page 44.

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