Chapter

IV-10

Advanced Topics

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This chapter contains material on topics of interest to advanced Igor users.

Regular Modules

Regular modules, or "modules" for short, provide a way to avoid name conflicts between procedure files. Regular modules are distinct from "independent modules" which are discussed in the next section.

Igor's module concept provides a way to group related procedure files and to prevent name conflicts between procedure packages.

By default, a procedure file is in the built-in ProcGlobal module. A procedure file that does not contain a #pragma ModuleName statement (or a #pragma IndependentModule statement - discussed below) is in ProcGlobal. Neither #pragma ModuleName nor #pragma IndependentModule are allowed in the built-in procedure window which is always in ProcGlobal.

When you execute a function from the command line or use the **Execute** operation, you are operating in the ProcGlobal context.

Functions in ProcGlobal are either public, or, if they are declared using the static keyword, private. For example:

```
// In a procedure file with no #pragma ModuleName or #pragma IndependentModule

static Function Test()           // Private to its procedure file
   Print "Test in ProcGlobal"
End

Function TestInProcGlobal()      // Public
   Print "TestInProcGlobal in ProcGlobal"
End
```

Because it is declared static, the Test function is private to its procedure file. Each procedure file can have its own static Test function without causing a name conflict. The TestInProcGlobal function is public so there can be only one public function with this name.

In this example the static Test function is accessible only from the procedure file in which it is defined. Sometimes you have a need to avoid name conflicts but still want to be able to call functions from other procedure files, from control action procedures or from the command line. This is where a regular module is useful.

You specify that a procedure file is in a different module (other than ProcGlobal) using the ModuleName pragma. For example:

```
#pragma ModuleName = ModuleA     // The following procedures are in ModuleA

static Function Test()           // Semi-private
   Print "Test in ModuleA"
End

Function TestModuleA()           // Public
   Print "Test in ModuleA"
End
```

Because it is declared static, this Test function does not conflict with Test functions in other procedure files. But because it is in a named regular module (ModuleA), it can be called from other procedure files using a qualified name:

```
ModuleA#Test()                   // Call Test from ModuleA
```

This qualified name syntax overrides the static nature of Test and tells Igor that you want to execute the Test function defined in ModuleA. The only way to access a static function from another procedure file is to put it in a regular module and use a qualified name.

If you are writing a non-trivial set of procedures, it is a good idea to use a module and to declare your functions static, especially if other people will be using your code. This prevents name conflicts with other procedures that you or other programmers write. Make sure to choose a distinctive module name.

Regular Modules in Action Procedures and Hook Functions

Control action procedures and hook functions are called by Igor at certain times. They are executed in the ProcGlobal context. This means that a static function can not be used as an action procedure or a hook function without using a qualified name. For example:

```
// In a procedure file with no #pragma ModuleName or #pragma IndependentModule

static Function ButtonProc(ba) : ButtonControl
   STRUCT WMButtonAction &ba

   switch (ba.eventCode)
      case 2: // mouse up
         Print "Running ProcGlobal#ButtonProc"
         break
   endswitch

   return 0
End

Function CreatePanel()
   NewPanel /W=(375,148,677,228)
   // This will not work because ButtonProc is private to the procedure file
   Button button0,pos={106,23},size={98,20},title="Click Me"
   Button button0,proc=ButtonProc
End
```

When you click the Click Me button, Igor tries to run the ButtonProc action procedure. However, because it is static, it is not accessible from outside the procedure file so Igor displays an error.

There are two possible solutions for this problem:

1. Make ButtonProc global by removing the static keyword
2. Use a regular module

If you make ButtonProc global, you run the risk of a name conflict with some other programmer's ButtonProc function. You can prevent this by changing ButtonProc to a very distinctive name, like AcmeDataAcqButtonProc, but this becomes tedious.

Here is the solution using a module:

```
#pragma ModuleName = RegularModuleA

static Function ButtonProc(ba) : ButtonControl
   STRUCT WMButtonAction &ba

   switch (ba.eventCode)
      case 2: // mouse up
         Print "Running RegularModuleA#ButtonProc"
         break
   endswitch

   return 0
End
```

```
static Function CreatePanel()
   NewPanel /W=(375,148,677,228)
   Button button0,pos={106,23},size={98,20},title="Click Me"
   Button button0,proc=RegularModuleA#ButtonProc
End
```

RegularModuleA is the name we have chosen for the regular module for demonstration purposes. You should choose a more descriptive module name.

The use of a qualified name, RegularModuleA#ButtonProc, allows Igor to find and execute the static ButtonProc function in the RegularModuleA module even though ButtonProc is running in the ProcGlobal context.

To protect the CreatePanel function from name conflicts we also made it static. To create the panel, execute:

```
RegularModuleA#CreatePanel()
```

Regular Modules and User-Defined Menus

Menu item execution text also runs in the ProcGlobal context. If you want to call a routine in a regular module you must use a qualified name.

Continuing the example from the preceding section, here is how you would write a menu definition:

```
#pragma ModuleName = RegularModuleA

Menu "Macros"
   "Create Panel", RegularModuleA#CreatePanel()
End
```

See also **Independent Modules** below, **Controls and Control Panels** on page III-365, **User-Defined Hook Functions** on page IV-264 and **User-Defined Menus** on page IV-117.

Independent Modules

An independent module is a set of procedure files that are compiled separately from all other procedures. Because it is compiled separately, an independent module can run when other procedures are in an uncompiled state because the user is editing them or because an error occurred in the last compile. This allows the independent module's control panels and menus to continue to work regardless of user programming errors.

Creating an independent module adds complexity and requires a solid understanding of Igor programming. You should use an independent module if it is important that your procedures be runnable at all times. For example, if you have created a data acquisition package that must run regardless of what the user is doing, that would be a good candidate for an independent module.

A file is designated as being part of an independent module using the IndependentModule pragma:

```
#pragma IndependentModule = imName
```

Make sure to use a distinctive name for your independent module.

The IndependentModule pragma is not allowed in the built-in procedure window which is always in the ProcGlobal module.

An independent module creates an independent namespace. Function names in an independent module do not conflict with the same names used in other modules. To call an independent module function from another module, including the default ProcGlobal module, the function must be public (non-static) and you must use a qualified name as illustrated in the next section.

Independent Modules - A Simple Example

Here is a simple example using an independent module. This code must be in its own procedure file and not in the built-in procedure file:

```
#pragma IndependentModule = IndependentModuleA

static Function Test()              // static means private to file
   Print "Test in IndependentModuleA"
End

// This must be non-static to call from command line (ProcGlobal context)
Function CallTestInIndependentModuleA()
   Test()
End
```

From the command line (the ProcGlobal context):

```
CallTestInIndependentModuleA()                      // Error

IndependentModuleA#CallTestInIndependentModuleA()   // OK

IndependentModuleA#Test()                           // Error
```

The first command does not work because the functions in the independent module are accessible only using a qualified name. The second command does work because it uses a qualified name and because the function is public (non-static). The third command does not work because the function is private (static) and therefore is accessible only from the file in which it is defined. A static function in an independent module is not accessible from outside the procedure file in which it is defined unless it is in an enclosed regular module as described under **Regular Modules Within Independent Modules** on page IV-228.

SetIgorOption IndependentModuleDev=1

By default, the debugger is disabled for independent modules. It can be enabled using:

```
SetIgorOption IndependentModuleDev=1
```

Also by default, independent module procedure windows are not listed in the Windows→Procedure Windows submenu unless you use `SetIgorOption IndependentModuleDev=1`.

When `SetIgorOption IndependentModuleDev=1` is in effect, the Windows→Procedure Windows submenu shows all procedure windows, and those that belong to an independent module are listed with the independent module name in brackets. For example:

```
DemoLoader.ipf [WMDemoLoader]
```

This bracket syntax is used in the **WinList**, **FunctionList**, **DisplayProcedure**, and **ProcedureText** functions and operations.

To get the user experience, as opposed to the programmer experience, return to normal operation by executing:

```
SetIgorOption IndependentModuleDev=0
```

Independent Module Development Tips

Development of an independent module may be easier if it is first done as for normal code. Add the module declaration

```
#pragma IndependentModule = moduleName
```

only after the code has been fully debugged and is working properly.

A procedure file that is designed to be #included should ideally work inside or outside of an independent module. Read the sections on independent modules below to learn what the issues are.

When developing an independent module, you will usually want to execute:

```
SetIgorOption IndependentModuleDev=1
```

Independent Modules and #include

If you #include a procedure file from an independent module, Igor copies the #included file into memory and makes it part of the independent module by inserting a #pragma IndependentModule statement at the start of the copy. If the same file is included several times, there will be several copies, each with a different independent module name.

Warning: Do not edit the procedure windows created by #including into an independent module because they are temporary and your changes will not be saved. You would not want to save them anyway because Igor has modified them.

Warning: Do not #include files that already contain a #pragma IndependentModule statement unless the independent module name is the same.

Limitations of Independent Modules

Independent modules are not for every-day programming and are more difficult to create than normal modules because of the following limitations:

1. Macros and Procs are not supported.
2. Button and control dialogs do not list functions in an independent module.
3. Functions in an independent module can not call functions in other modules except through the Execute operation.

Independent Modules in Action Procedures and Hook Functions

Normally you must use a qualified name to invoke a function defined in an independent module from the ProcGlobal context. Control action procedures and hook functions execute in the ProcGlobal context. But, as a convenience and to make #include files more useful, Igor eliminates this requirement when you create controls and specify hook functions from a user-defined function in an independent module.

When you execute an operation that creates a control or specifies a hook function while running in an independent module, Igor examines the specified control action function name or hook function name. If the named function is defined in the same independent module, Igor automatically inserts the independent module name. This means you can write something like:

```
#pragma IndependentModule = IndependentModuleA
Button b0, proc=ButtonProc
SetWindow hook(Hook1)=HookFunc
```

You don't have to write:

```
#pragma IndependentModule = IndependentModuleA
Button b0, proc=IndependentModuleA#ButtonProc
SetWindow hook(Hook1)=IndependentModuleA#HookFunc
```

Such independent module name insertion is only done when an operation called from a function defined in an independent module. It is not done if the operation is executed from the command line or via **Execute**.

The control action function or hook function must be public (non-static) except as describe under **Regular Modules Within Independent Modules** on page IV-228.

Here is a working example:

```
#pragma IndependentModule = IndependentModuleA
```

```
Function ButtonProc(ba) : ButtonControl    // Must not be static
   STRUCT WMButtonAction &ba

   switch (ba.eventCode)
      case 2: // mouse up
         Print "Running IndependentModuleA#ButtonProc"
         break
   endswitch

   return 0
End

Function CreatePanel()
   NewPanel /W=(375,148,677,228)
   Button button0,pos={106,23},size={98,20},title="Click Me"
   Button button0,proc=ButtonProc
End
```

Independent Modules and User-Defined Menus

Independent modules can contain user-defined menus. When you choose a user-defined menu item, Igor determines if the menu item was defined in an independent module. If so, and if the menu item's execution text starts with a call to a function defined in the independent module, then Igor prepends the independent module name before executing the text. This means that the second and third menu items in the following example both call IndependentModuleA#DoAnalysis:

```
#pragma IndependentModule = IndependentModuleA

Menu "Macros"
   "Load Data File/1", Beep; LoadWave/G
   "Do Analysis/2", DoAnalysis() // Igor automatically prepends IndependentModuleA#
   "Do Analysis/3", IndependentModuleA#DoAnalysis()
End

Function DoAnalysis()
   Print "DoAnalysis in IndependentModuleA"
End
```

This behavior on Igor's part makes it possible to #include a procedure file that creates menu items into an independent module and have the menu items work. However, in many cases you will not want a #included file's menu items to appear. You can suppress them using `menus=0` option in the #include statement. See **Turning the Included File’s Menus Off** on page IV-156.

Note: If a procedure file with menu definitions is included into multiple independent modules, the menus are repeatedly defined (see **Independent Modules and #include** on page IV-226). Judicious use of the menus=0 option in the #include statements helps prevent this. See **Turning the Included File’s Menus Off** on page IV-156.

When the execution text doesn't start with a user-defined function name, as for the first menu item in this example, Igor executes the text without altering it.

Independent Modules and Popup Menus

In an independent module, implementing a popup menu whose items are determined by a function call at click time requires special care. For example, outside of an independent module, this works:

```
Function/S MyPopMenuList()
   return "Item 1;Item2;"
End
...
PopupMenu pop0 value=#"MyPopMenuList()"       // Note the quotation marks
```

But inside an independent module you need this:

```
#pragma IndependentModule=MyIM
Function/S MyPopMenuList()
   return "Item 1;Item2;"
End
...
String cmd= GetIndependentModuleName()+"#MyPopMenuList()"
PopupMenu pop0 value=#cmd                    // No enclosing quotation marks
```

GetIndependentModuleName returns the name of the independent module to which the currently-running function belongs or "ProcGlobal" if the currently-running function is not part of an independent module.

You could change the command string to:

```
PopupMenu pop0 value=#"MyIM##MyPopMenuList()"
```

but using GetIndependentModuleName allows you to disable the IndependentModule pragma by commenting it out and have the code still work which can be useful during development. With the pragma commented out you are running in ProcGlobal context and GetIndependentModuleName returns "ProcGlobal".

When the user clicks the popup menu, Igor generates the menu items by evaluating the text specified by the PopupMenu value keyword as an Igor expression. The expression (`"MyIM#MyPopMenuList()"` in this case) is evaluated in the ProcGlobal context. In order for Igor to find the function in the independent module, it must be public (non-static), except as describe under **Regular Modules Within Independent Modules** on page IV-228, and you must use a qualified name.

Note that `#cmd` is not the same as `#"cmd"`. The `#cmd` form was introduced with Igor Pro 6. The string variable cmd is evaluated when PopupMenu runs which occurs in the context of the independent module. The contents of cmd (`"MyIM#MyPopMenuList()"` in this case) are stored in the popup menu's internal data structure. When the popup menu is clicked, Igor evaluates the stored text as an Igor expression. This causes the function `MyIM#MyPopMenuList` to run.

With the older `#"cmd"` syntax, the stored text is evaluated only when the popup menu is clicked, not when the PopupMenu operation runs, and this evaluation occurs in the ProcGlobal context. It is too late to capture the independent module in which the text should be evaluated.

Regular Modules Within Independent Modules

It is usually not necessary but you can create a regular module within an independent module. For example:

```
#pragma IndependentModule = IndependentModuleA
#pragma ModuleName = RegularModuleA
Function Test()
   Print "Test in RegularModuleA within IndependentModuleA"
End
```

Here RegularModuleA is a regular module within IndependentModuleA.

To call the function Test from outside of the independent module you must qualify the call like this:

```
IndependentModuleA#RegularModuleA#Test()
```

This illustrates that the independent module establishes its own namespace (IndependentModuleA) which can host one level of sub-namespace (RegularModuleA). By contrast, a regular module creates a namespace within the global namespace (called ProcGlobal) and can not host additional sub-namespaces.

This nesting of modules is useful to prevent name conflicts in a large independent module project comprising multiple procedure files. Otherwise it is not necessary.

Because all procedure files in a given independent module are compiled separately from all other files, function names never conflict with those outside the group and there is little or no need to use the static

designation on functions in an independent module. However, if need be, you can call static functions in a regular module inside an independent module from outside the independent module using a triple-qualified name:

```
IndependentModuleName#RegularModuleName#FunctionName()
```

Calling Routines From Other Modules

Code in an independent module can not directly call routines in other modules and usually should not need to. If you must call a routine from another module, you can do it using the **Execute** operation. You must use a qualified name. For example:

```
Execute "ProcGlobal#foo()"
```

To call a function in a regular module, you must prepend ProcGlobal and the regular module name to the function name:

```
Execute "ProcGlobal#MyRegularModule#foo()"
```

Calling a nonstatic function in a different independent modules requires prepending just the other independent module name:

```
Execute "OtherIndependentModule#bar()"
```

Calling static functions in other independent modules requires prepending the independent module name and a regular module name:

```
Execute "OtherIndependentModule#RegularModuleName#staticbar()"
```

Using Execute Within an Independent Module

If you need to call a function in the current independent module using Execute, you can compose the name using the **GetIndependentModuleName** function. For example, outside of an independent module the commands would be:

```
String cmd = "WS_UpdateWaveSelectorWidget(\"Panel0\", \"selectorWidgetName\")"
Execute cmd
```

But inside an independent module the commands are:

```
#pragma IndependentModule=MyIM
String cmd="WS_UpdateWaveSelectorWidget(\"Panel0\", \"selectorWidgetName\")"
cmd = GetIndependentModuleName() + "#" + cmd    // Make qualified name
Execute cmd
```

You could change the command string to:

```
cmd = "MyIM#" + cmd
```

but using GetIndependentModuleName allows you to disable the IndependentModule pragma by commenting it out and have the code still work which can be useful during development. With the pragma commented out you are running in ProcGlobal context and GetIndependentModuleName returns "ProcGlobal".

Independent Modules and Dependencies

GetIndependentModuleName is also useful for defining dependencies using functions in the current independent module. Dependencies are evaluated in the global procedure context (ProcGlobal). In order for dependencies to evaluate correctly, the dependency must use GetIndependentModuleName to create a formula to pass to the **SetFormula** operation. For example, outside of an independent module, this works:

```
String formula = "foo(root:wave0)"
SetFormula root:aVariable $formula
```

But inside an independent module you need this:

```
#pragma IndependentModule=MyIM
String formula = GetIndependentModuleName() + "#foo(root:wave0)"
SetFormula root:aVariable $formula
```

Independent Modules and Pictures

To allow DrawPICT to use a picture in the picture gallery, you must prepend GalleryGlobal# to the picture name:

```
DrawPICT 0,0,1,1,GalleryGlobal#PICT_0
```

Without GalleryGlobal, only proc pictures can be used in an independent module.

Making Regular Procedures Independent-Module-Compatible

You may want to make an existing set of procedures into an independent module. Alternatively, you may want to make an existing procedure independent-module-compatible so that it can be #included into an independent module. This section outlines the necessary steps.

1. If you are creating an independent module, add the IndependentModule pragma:
   ```
   #pragma IndependentModule=<NameOfIndependentModule>
   ```
2. Change any Macro or Proc procedures to functions.
3. Make Execute commands suitable for running in the ProcGlobal context or in an independent module using GetIndependentModuleName. See **Using Execute Within an Independent Module** on page IV-229.
4. Make PopupMenu controls that call a string function to populate the menu work in the ProcGlobal context or in an independent module using GetIndependentModuleName. See **Independent Modules and Popup Menus** on page IV-227.
5. Make any dependencies work in the ProcGlobal context or in an independent module using GetIndependentModuleName. See **Independent Modules and Dependencies** on page IV-229.

See also **Regular Modules** on page IV-222, **Controls and Control Panels** on page III-365, **User-Defined Hook Functions** on page IV-264, **User-Defined Menus** on page IV-117, and **GetIndependentModuleName** on page V-261.

Sound

Two operations are provided for playing of sound through the computer speakers:

- PlaySound
- PlaySnd (*Macintosh*)

The **PlaySound** operation takes the sound data from a wave.

The obsolete **PlaySnd** operation gets its data from a Macintosh 'snd ' resource stored in a file.

A number of sound input operations are provided: **SoundInStatus** (page V-758) , **SoundInSet** (page V-757) , **SoundInRecord** (page V-756) , **SoundInStartChart** (page V-757) and **SoundInStopChart** (page V-758) . Several example experiments that use these routines can be found in your Igor Pro 7 Folder in the Examples folder.

The **SoundLoadWave** operation loads various sound file formats into waves and **SoundSaveWave** saves wave data to sound files. These operations replace SndLoadWave, SoundSaveAIFF and SoundSaveWAV from the obsolete SndLoadSaveWave XOP.

Movies

You can play movies in Igor. You can also create movies, optionally with a soundtrack. And you can extract frames from movies for analysis.

On Macintosh Igor can play QuickTime and AVI movies. It can create QuickTime movies only.

On Windows Igor can create and play AVI movies only.

Playing Movies

Use the PlayMovie operation to play a movie whether the movie was created in Igor or not.

Playing a movie requires that you have the codecs required by the movie installed on your machine.

On Macintosh, both QuickTime and AVI movies open in the Igor application.

On Windows, AVI movies open in your default movie viewing program - typically Windows Media Player.

Creating Movies

You can create a movie from a graph, page layout, or Gizmo window. To do this, you write a procedure that modifies the window and adds a frame to the movie in a loop. On Windows, you can include audio.

Here are the operations used to create and play a movie:

- **NewMovie**
- **AddMovieFrame**
- **AddMovieAudio**
- **CloseMovie**
- **PlayMovie**
- **PlayMovieAction**

The NewMovie operation creates a movie file and also defines the movie frame rate and optional audio track specifications.

On Macintosh NewMovie always creates a QuickTime movie and the /A (AVI) flag is ignored.

On Windows NewMovie creates an AVI movie.

Before calling NewMovie, you need to prepare the first frame of your movie as the target graph, page layout, or Gizmo window.

If you will be using audio you also need to prepare a sound wave. The sound wave can be of any time duration but usually will either be the entire length of the movie or will be the length of one video frame. As of Igor Pro 7, sound is not supported on Macintosh.

After creating the file and the first video frame and optional audio, you use AddMovieFrame to add as many video frames as you wish. You may also add more audio using the AddMovieAudio operation. Finally you use the CloseMovie and PlayMovie operations.

When you write a procedure to generate a movie, you need to call the DoUpdate operation after all modifications to the graph, page layout, or Gizmo window and before calling AddMovieFrame. This allows Igor to process any changes you have made to the window.

In addition to creating a movie from a window, you can also create movies from pictures in the picture gallery (see **Pictures** on page III-448) using the /PICT flag with NewMovie and AddMovieFrame. You can put pictures of Igor graphs, tables, page layouts, and Gizmo plots in the gallery using **SavePICT**.

Extracting Movie Frames

You can extract individual frames from a movie and can control movie playback using **PlayMovieAction**.

Movie Programming Examples

For examples of programming with movies, choose File→Example Experiments→Movies & Audio.

Timing

There are two methods you can use when you want to measure elapsed time:

- The ticks counter using the ticks function
- The microsecond timer using **StartMSTimer** and **StopMSTimer**

Ticks Counter

You can easily measure elapsed time with a precision of 1/60th of a second using the ticks function. It returns the tick count which starts at zero when you first start your computer and is incremented at a rate of approximately 60 Hz rate from then on.

Here is an example of typical use:

```
…
Variable t0
…
t0= ticks
<operations you wish to time>
printf "Elapsed time was %g seconds\r",(ticks-t0)/60
…
```

Microsecond Timer

You can measure elapsed time to microsecond accuracy for durations up to 35 minutes using the microsecond timer. See the **StartMSTimer** function (page V-775) for details and an example.

Packages

A package is a set of files that adds significant functionality to Igor. Packages consist of procedure files and may also include XOPs, help files and other supporting files.

A package usually adds one or more items to Igor's menus that allow the user to interactively load the package, access its functionality, and unload the package.

A package typically provides some level of user-interface, such as a menu item and a control panel, for accessing the added functionality. It may store settings in experiments or in global preferences.

A package is typically loaded into memory and unloaded at the user's request.

Igor comes pre-configured with numerous WaveMetrics packages accessed through the Data→Packages, Analysis→Packages, Misc→Packages, Windows→New→Packages and Graph→Packages submenus as well as others. Take a peek at these submenus to see what packages are supplied with Igor.

Menu items for WaveMetrics packages are added to Igor's menus by the WMMenus.ipf procedure file which is shipped in the Igor Procedures folder. WMMenus.ipf is hidden unless you enable independent module development. See **Independent Modules** on page IV-224.

Creating a Package

This section shows how to create a package through a simple example. The package is called "Sample Package". It adds a Load Sample Package item to the Macros menu. When the user chooses Load Sample Package, the package's procedure file is loaded. This adds two additional items to the Macros menu: Hello From Sample Package and Unload Sample Package.

The package consists of two procedure files stored in a folder in the Igor Pro User Files folder. If you are not familiar with Igor Pro User Files, take a short detour and read **Special Folders** on page II-29 and **Igor Pro User Files** on page II-31.

The sample package is installed as follows:

```
Igor Pro 7 User Files
   Sample Package
      Sample Package Loader.ipf
      Sample Package.ipf
   Igor Procedures
      Alias or shortcut pointing to the "Sample Package Loader.ipf" file
   User Procedures
      Alias or shortcut pointing to the "Sample Package" folder
```

Putting the alias/shortcut for the "Sample Package Loader.ipf" in Igor Procedures causes Igor to load that file at launch time. The file adds the "Load Sample Package" item to the Macros menu. See **Global Procedure Files** on page III-353 for details.

Putting the alias/shortcut for the "Sample Package" folder in User Procedures causes Igor to search that folder when a #include is invoked. See **Shared Procedure Files** on page III-354 for details.

A real package might include other procedure files and a help file in the "Sample Package" folder.

To try this out yourself, follow these steps:

1. Create the "Sample Package" folder in your Igor Pro User Files folder.

   You can locate your Igor Pro User Files folder using the Help menu.
2. Create a new procedure file named "Sample Package Loader.ipf" in the "Sample Package" folder and enter the following contents in the file:

```
Menu "Macros"
   "Load Sample Package", /Q, LoadSamplePackage()
End

Function LoadSamplePackage()
   Execute/P/Q/Z "INSERTINCLUDE \"Sample Package\""
   Execute/P/Q/Z "COMPILEPROCEDURES "// Note the space before final quote
End
```

   Save the procedure file.
3. Create a new procedure file named "Sample Package.ipf" in the "Sample Package" folder and enter the following contents in the file:

```
Menu "Macros"
   "Hello From Sample Package", HelloFromSamplePackage()
   "Unload Sample Package", UnloadSamplePackage()
End

Function HelloFromSamplePackage()
   DoAlert /T="Sample Package Wants to Say" 0, "Hello!"
End

Function UnloadSamplePackage()
   Execute /P /Q /Z "DELETEINCLUDE \"Sample Package\""
   Execute /P /Q /Z "COMPILEPROCEDURES "// Note the space before final quote
End
```

   Save the procedure file.
4. In the desktop, make an alias or shortcut for "Sample Package Loader.ipf" file and put it in the Igor Procedures folder in the Igor Pro User Files folder.

   This causes Igor to load the "Sample Package Loader.ipf" file at launch time. This is how the Load Sample Package menu item gets into the Macros menu.
5. In the desktop, make an alias or shortcut for the "Sample Package" folder and put it in the User Procedures folder in the Igor Pro User Files folder.

This causes Igor to search the "Sample Package" folder when a #include is invoked. This allows Igor to find the "Sample Package.ipf" file when it is #included.

6. Quit and restart Igor so that Igor will load the "Sample Package Loader.ipf" file.

   If you prefer you can just manually make sure that "Sample Package Loader.ipf" is open and "Sample Package.ipf" is closed. This simulates the state of affairs after restarting Igor.

7. Choose Windows→Procedure Windows and verify that Igor has loaded the "Sample Package Loader.ipf" file.
8. Click the Macros menu and verify that the "Load Sample Package" item is present.
9. Choose Macros→Load Sample Package.

   The LoadSamplePackage function runs, adds a #include statement to the built-in procedure window, and forces procedures to be recompiled. This cause Igor to load the "Sample Package.ipf" procedure file which contains the bulk of the package's procedures and adds items to the Macros menu.

10. Click the Macros menu and notice that the "Hello From Sample Package" and "Unload Sample Package" items have been added.
11. Choose Macros→Hello From Sample Package.

    The package displays an alert. A real package would do something more exciting.

12. Choose Macros→Unload Sample Package.

    The UnloadSamplePackage function runs, removes the #include statement from the built-in procedure window, and forces procedures to be recompiled. This cause Igor to unload the "Sample Package.ipf" procedure.

13. Click the Macros menu and notice that the "Hello From Sample Package" and "Unload Sample Package" items have been removed.

Most real packages do not create Unload menu items. Instead they provide an Unload Package button in a control panel or automatically unload when a control panel is closed. Or they might not support unloading.

A real package typically does not include "Package" in its name or in its menu items.

Lightweight Packages

A lightweight package is one that consists of at most a few procedure files and does not create clutter in the current experiment unless it is actually used.

If your package is lightweight you might prefer to dispense with loading and unload it and just keep it loaded all the time. To do this you would organize your files like this:

```
Igor Pro 7 User Files
   Your Package
      Your Package Part 1.ipf
      Your Package Part 2.ipf
   Igor Procedures
      Alias or shortcut pointing to the "Your Package" folder
```

Here both of your package procedure files are global, meaning that Igor loads them at launch time and never unloads them. You do not need procedures for loading and unloading your package.

If you have an ultra-light package, consisting of just a single procedure file, you can dispense with the "Your Package" folder and put the procedure file directly in the Igor Procedures folder.

Managing Package Data

When you create a package of procedures, you need some place to store private data used by the package to keep track of its state. It's important to keep this data separate from the user's data to avoid clutter and to protect your data from inadvertent changes.

Private data should be stored in a data folder named after the package inside a generic data folder named Packages. For example, if your package is named My Package you would store your private data in `root:Packages:My Package`.

There are two general types of private data that you might need to store: overall package data and per-instance data. For example, for a data acquisition package, you may need to store data describing the state of the acquisition as a whole and other data on a per-channel basis.

Creating and Accessing the Package Data Folder

This section demonstrates the recommended way to create and access a package data folder. We use a bottleneck function that returns a **DFREF** for the package data folder. If the package data folder does not yet exist, the bottleneck function creates and initializes it. This way calling functions don't need to worry about whether the package data folder has been created.

First we write a function to create and initialize the package data folder:

```
Function/DF CreatePackageData()      // Called only from GetPackageDFREF
   // Create the package data folder
   NewDataFolder/O root:Packages
   NewDataFolder/O root:Packages:'My Package'

   // Create a data folder reference variable
   DFREF dfr = root:Packages:'My Package'

   // Create and initialize package data
   Variable/G dfr:gVar1 = 1.0
   String/G dfr:gStr1 = "hello"
   Make/O dfr:wave1
   WAVE wave1 = dfr:wave1
   wave1= x^2

   return dfr
End
```

Now we can write the bottleneck function:

```
Function/DF GetPackageDFREF()
   DFREF dfr = root:Packages:'My Package'
   if (DataFolderRefStatus(dfr) != 1)      // Data folder does not exist?
      DFREF dfr = CreatePackageData()      // Create package data folder
   endif
   return dfr
End
```

GetPackageDFREF would be used like this:

```
Function/DF DemoPackageDFREF()
   DFREF dfr = GetPackageDFREF()

   // Read a package variable
   NVAR gVar1 = dfr:gVar1
   Printf "On entry gVar1=%g\r", gVar1

   // Write to a package variable
   gVar1 += 1
   Printf "Now gVar1=%g\r", gVar1
End
```

All functions that access the package data folder should do so through GetPackageDFREF. The calling functions do not need to worry about whether the data folder has been created and initialized because GetPackageDFREF does this for them.

Creating and Accessing the Package Per-Instance Data Folders

Here we extend the technique of the preceding section to handle per-instance data. This example shows how you might handle per-channel data in a data acquisition package. If your package does not use per-instance data then you can skip this section.

First we write a function to create and initialize the per-instance package data folder:

```
Function/DF CreatePackageChannelData(channel)    // Called only from
   Variable channel     // 0 to 3                // GetPackageChannelDFREF

   DFREF dfr = GetPackageDFREF()    // Access main package data folder

   String dfName = "Channel" + num2istr(channel)   // Channel0, Channel1, ...

   // Create the package channel data folder
   NewDataFolder/O dfr:$dfName

   // Create a data folder reference variable
   DFREF channelDFR = dfr:$dfName

   // Initialize per-instance data
   Variable/G channelDFR:gGain = 5.0
   Variable/G channelDFR:gOffset = 0.0

   return channelDFR
End
```

Now we can write the bottleneck function:

```
Function/DF GetPackageChannelDFREF(channel)
   Variable channel     // 0 to 3

   DFREF dfr = GetPackageDFREF()    // Access main package data folder

   String dfName = "Channel" + num2istr(channel)   // Channel0, Channel1, ...
   DFREF channelDFR = dfr:$dfName
   if (DataFolderRefStatus(channelDFR) != 1)    // Data folder does not exist?
      DFREF channelDFR = CreatePackageChannelData(channel)  // Create it
   endif
   return channelDFR
End
```

GetPackageChannelDFREF would be used like this:

```
Function/DF DemoPackageChannelDFREF(channel)
   Variable channel     // 0 to 3

   DFREF channelDFR = GetPackageChannelDFREF(channel)

   // Read a package variables
   NVAR gGain = channelDFR:gGain
   NVAR gOffset = channelDFR:gOffset
   Printf "Channel %d: Gain=%g, offset=%g\r", channel, gGain, gOffset
End
```

All functions that access a package channel data folder should do so through GetPackageChannelDFREF. The calling functions do not need to worry about whether the data folder has been created and initialized because GetPackageChannelDFREF does this for them.

Saving Package Preferences

If you are writing a sophisticated package of Igor procedures you may want to save preferences for your package. For example, if your package creates a control panel that can be opened in any experiment, you may want it to remember its position on screen between invocations. Or you may want to remember various settings in the panel from one invocation to the next.

Such “state” information can be stored either separately in each experiment or it can be stored just once for all experiments in preferences. These two approaches both have their place, depending on circumstances. But, if your package creates a control panel that is intended to be present at all times and used in any experiment, then the preferences approach is usually the best fit.

If you choose the preferences approach, you will store your package preference file in a directory created for your package. Your package directory will be in the Packages directory, inside Igor’s own preferences directory.

The location of Igor’s Packages directory depends on the operating system and the particular user’s configuration. You can find where it is on a particular system by executing:

```
Print SpecialDirPath("Packages", 0, 0, 0)
```

Important:You must choose a very distinctive name for your package because that is the only thing that prevents some other package from overwriting yours. All package names starting with “WM” are reserved for WaveMetrics.

A package name is limited to 31 bytes and must be a legal name for a directory on disk.

There are two ways to store package preference data:

- In a special-format binary file stored in your package directory
- As Igor waves and variables in an Igor experiment file stored in your package directory

The special-format binary file approach is relatively simple to implement but is not suitable for storing very large amounts of data. In most cases it is not necessary to store very large amounts of data so this is the way to go.

The use of the Igor experiment file supports storing a large amount of preference data but creates a problem of synchronizing your preference data stored in memory and your preference data stored on disk. It also leads to a proliferation of preference data stored in various experiments. You should avoid using this technique if possible.

Saving Package Preferences in a Special-Format Binary File

This approach supports preference data consisting of a collection of numeric and string data. You define a structure encapsulating your package preference data. You use the **LoadPackagePreferences** operation (page V-440) to load your data from disk and the **SavePackagePreferences** operation (page V-703) to save it to disk.

SavePackagePreferences stores data from your package’s preferences data structure in memory. LoadPackagePreferences returns that data to you via the same structure.

SavePackagePreferences also creates a directory for your package preferences and stores your data in a file in that directory. Your package directory is located in the Packages directory in Igor’s preferences directory. The job of storing the preferences data in the file is handled transparently which, by default, automatically flushes your data to the file when the current experiment is saved or closed and when Igor quits.

You would call LoadPackagePreferences every time you need to access your package preference data and SavePackagePreferences every time you want to change your package preference data. You pass to these operations an instance of a structure that you define.

Here are example functions from the Package Preferences Demo experiment that use the LoadPackagePreferences and SavePackagePreferences operations to implement preferences for a particular package:

```
// NOTE: The package name you choose must be distinctive!
static StrConstant kPackageName = "Acme Data Acquisition"
static StrConstant kPrefsFileName = "PanelPreferences.bin"
```

```
static Constant kPrefsVersion = 100
static Constant kPrefsRecordID = 0

Structure AcmeDataAcqPrefs
	uint32version	// Preferences structure version number. 100 means 1.00.
	double panelCoords[4]		// left, top, right, bottom
	uchar phaseLock
	uchar triggerMode
	double ampGain
	uint32 reserved[100]		// Reserved for future use
EndStructure

// DefaultPackagePrefsStruct(prefs)
// Sets prefs structure to default values.
static Function DefaultPackagePrefsStruct(prefs)
	STRUCT AcmeDataAcqPrefs &prefs

	prefs.version = kPrefsVersion

	prefs.panelCoords[0] = 5		// Left
	prefs.panelCoords[1] = 40		// Top
	prefs.panelCoords[2] = 5+190		// Right
	prefs.panelCoords[3] = 40+125		// Bottom
	prefs.phaseLock = 1
	prefs.triggerMode = 1
	prefs.ampGain = 1.0

	Variable i
	for(i=0; i<100; i+=1)
		prefs.reserved[i] = 0
	endfor
End

// SyncPackagePrefsStruct(prefs)
// Syncs package prefs structures to match state of panel.
// Call this only if the panel exists.
static Function SyncPackagePrefsStruct(prefs)
	STRUCT AcmeDataAcqPrefs &prefs

	// Panel does exists. Set prefs to match panel settings.
	prefs.version = kPrefsVersion

	GetWindow AcmeDataAcqPanel wsize
	// NewPanel uses device coordinates. We therefore need to scale from
	// points (returned by GetWindow) to device units for windows created
	// by NewPanel.
	Variable scale = ScreenResolution / 72
	prefs.panelCoords[0] = V_left * scale
	prefs.panelCoords[1] = V_top * scale
	prefs.panelCoords[2] = V_right * scale
	prefs.panelCoords[3] = V_bottom * scale

	ControlInfo /W=AcmeDataAcqPanel PhaseLock
	prefs.phaseLock = V_Value		// 0=unchecked; 1=checked

	ControlInfo /W=AcmeDataAcqPanel TriggerMode
	prefs.triggerMode = V_Value		// Menu item number starting from on

	ControlInfo /W=AcmeDataAcqPanel AmpGain
	prefs.ampGain = str2num(S_value)	// 1, 2, 5 or 10
End

// InitPackagePrefsStruct(prefs)
// Sets prefs structures to match state of panel or
// to default values if panel does not exist.
static Function InitPackagePrefsStruct(prefs)
	STRUCT AcmeDataAcqPrefs &prefs

	DoWindow AcmeDataAcqPanel
	if (V_flag == 0)
		// Panel does not exist. Set prefs struct to default.
		DefaultPackagePrefsStruct(prefs)
	else
		// Panel does exists. Sync prefs struct to match panel state.
		SyncPackagePrefsStruct(prefs)
```

```
	endif
End

static Function LoadPackagePrefs(prefs)
	STRUCT AcmeDataAcqPrefs &prefs

	// This loads preferences from disk if they exist on disk.
	LoadPackagePreferences kPackageName, kPrefsFileName, kPrefsRecordID, prefs

	// If error or prefs not found or not valid, initialize them.
	if (V_flag!=0 || V_bytesRead==0 || prefs.version!=kPrefsVersion)
		InitPackagePrefsStruct(prefs) // Set from panel if it exists or to default values.
		SavePackagePrefs(prefs)       // Create initial prefs record.
	endif
End

static Function SavePackagePrefs(prefs)
	STRUCT AcmeDataAcqPrefs &prefs

	SavePackagePreferences kPackageName, kPrefsFileName, kPrefsRecordID, prefs
End
```

NOTE: The package preferences structure, AcmeDataAcqPrefs in this case, must not use fields of type Variable, String, WAVE, NVAR, SVAR or FUNCREF because these fields refer to data that may not exist when LoadPackagePreferences is called.

The structure can use fields of type char, uchar, int16, uint16, int32, uint32, int64, uint64, float and double as well as fixed-size arrays of these types and substructures with fields of these types.

Use the reserved field to add fields to the structure in a backward-compatible fashion. For example, a subsequent version of the structure might look like this:

```
Structure AcmeDataAcqPrefs
	uint32   // Preferences structure version number. 100 means 1.00.
	double panelCoords[4]      // left, top, right, bottom
	uchar phaseLock
	uchar triggerMode
	double ampGain
	uint32 triggerDelay
	uint32 reserved[99]        // Reserved for future use
EndStructure
```

Here the triggerDelay field was added and size of the reserved field was reduced to keep the overall size of the structure the same. The AcmeDataAcqLoadPackagePrefs function would also need to be changed to set the default value of the triggerDelay field.

If you need to change the structure such that its size changes or its fields are changed in an incompatible manner then you must change your structure version, which will overwrite old preferences with new preferences.

A functioning example using this technique can be found in:

“Igor Pro 7 Folder:Examples:Programming:Package Preferences Demo.pxp”

In the example above we store just one structure in the preference file. However LoadPackagePreferences and SavePackagePreferences allow storing any number of structures of the same or different types in the preference file. You can store either multiple instances of the same structure or multiple different structures. You must assign a unique nonnegative integer as a record ID for each structure stored and pass this record ID to LoadPackagePreferences and SavePackagePreferences. You could use this feature, for example, to store a different structure for each type of control panel that your package presents. Since all data is cached in memory you should not attempt to store hundreds or thousands of structures.

In almost all cases a particular package will need just one preference file. For the rare cases where this is inconvenient, LoadPackagePreferences and SavePackagePreferences allow each package to create any number of preference files, each with a distinct file name. All of the preference files for a particular package are stored in the same directory, the package’s preferences directory. Each file can store a different set of

structure. However, the code that implements this feature is not tuned to handle large numbers of files so you should not use this feature indiscriminately.

Saving Package Preferences in an Experiment File

This approach supports package preference data consisting of waves, numeric variables and string variables. It is more difficult to implement than the special-format binary file approach and is not recommended except for expert programmers and then only if the previously described approach is not suitable.

You use the SaveData operation to store your waves and variables in a packed experiment file in your package directory on disk. You can later use the LoadData operation to load the waves and variables into a new experiment.

You must create your package directory as illustrated by the SavePackagePrefs function below.

The following example functions save and load package preferences. These functions assume that the package preferences consist of all waves and variables at the top level of the package's data folder. You may need to customize these functions for your situation.

```
// SavePackagePrefs(packageName)
// Saves the top-level waves, numeric variables and string variables
// from the data folder for the named package into a file in the Igor
// preferences hierarchy on disk.
Function SavePackagePrefs(packageName)
	String packageName			// NOTE: Use a distinctive package name.

	// Get path to Packages preferences directory on disk.
	String fullPath = SpecialDirPath("Packages", 0, 0, 0)
	fullPath += packageName

	// Create a directory in the Packages directory for this package
	NewPath/O/C/Q tempPackagePrefsPath, fullPath

	fullPath += ":Preferences.pxp"

	DFREF saveDF = GetDataFolderDFR()
	SetDataFolder root:Packages:$packageName
	SaveData/O/Q fullPath			// Save the preference file
	SetDataFolder saveDF

	// Kill symbolic path but leave directory on disk.
	KillPath/Z tempPackagePrefsPath
End

// LoadPackagePrefs(packageName)
// Loads the data from the previously-saved package preference file,
// if it exist, into the package's data folder.
// Returns 0 if the preference file existed, -1 if it did not exist.
// In either case, this function creates the package's data folder if it
// does not already exist.
// LoadPackagePrefs does not affect any other data already in the
// package's data folder.
Function LoadPackagePrefs(packageName)
	String packageName			// NOTE: Use a distinctive package name.

	Variable result = -1
	DFREF saveDF = GetDataFolderDFR()

	NewDataFolder/O/S root:Packages		// Ensure root:Packages exists
	NewDataFolder/O/S $packageName		// Ensure package data folder exists

	// Find the disk directory in the Packages directory for this package
	String fullPath = SpecialDirPath("Packages", 0, 0, 0)
	fullPath += packageName
	GetFileFolderInfo/Q/Z fullPath
	if (V_Flag == 0)				// Disk directory exists?
		fullPath += ":Preferences.pxp"
		GetFileFolderInfo/Q/Z fullPath
		if (V_Flag == 0)			// Preference file exist?
			LoadData/O/R/Q fullPath		// Load the preference file.
			result = 0
		endif
	endif
```

```
    SetDataFolder saveDF
    return result
End
```

The hard part of using the experiment file for saving package preferences is not in saving or loading the package preference data but in choosing when to save and load it so that the latest preferences are always used. There is no ideal solution to this problem but here is one strategy:

1. When package preference data is needed (e.g., you are about to create your control panel and need to know the preferred coordinates), check if it exists in memory. If not load it from disk.
2. When the user does a New Experiment or quits Igor, if package preference data exists in memory, save it to disk. This requires that you create an IgorNewExperimentHook function and an IgorQuitHook function.
3. When the user opens an experiment file, if it contains package preference data, delete it and reload from disk. This requires that you create an AfterFileOpenHook function. This is necessary because the package preference data in the just opened experiment is likely to be older than the data in the package preference file.

Creating Your Own Help File

If you are an advanced user, you can create an Igor help file that extends the Igor help system. This is something you might want to do if you write a set of Igor procedures or extensions for use by your colleagues. If your procedures or extensions are generally useful, you might want to make them available to all Igor users. In either case, you can provide documentation in the form of an Igor help file.

Here are the steps for creating an Igor help file.

1. Create a formatted-text notebook.

   A good way to do this is to open the Igor Help File Template provided by WaveMetrics in the More Help Files folder. Alternatively, you can start by duplicating another WaveMetrics-supplied help file and then open it as a notebook using File→Open File→Notebook. Either way, you are starting with a notebook that contains the rulers used to format an Igor help file.
2. Choose Save Notebook As from the File menu to create a new file. Use a ".ihf" extension so that Igor will recognize it as a help file.
3. Enter your help text in the new file.
4. Save and kill the notebook.
5. Open the file as a help file using File→Open File→Help File.

When you open the file as a help file, it needs to be compiled. When Igor compiles a help file, it scans through it to find out where the topics start and end and makes a note of subtopics. When the compilation is finished, it saves the help file which now includes the help compiler information.

Once Igor has successfully compiled the help file, it acts like any other Igor help file. That is, when opened it appears in the Help Windows submenu, its topics will appear in the Help Browser, and you can click links to jump around.

Here are the steps for modifying a help file.

1. If the help file is open, kill it by pressing Option (*Macintosh*) or Alt (*Windows*) and clicking the close button.
2. Open it as a notebook, using File→Open File→Notebook.

   Alternatively, you can press Shift while choosing the file from File→Recent Files. Then, in the resulting dialog, specify that you want to open the file as a formatted notebook.
3. Modify it using normal editing techniques.
4. Choose Save Notebook from the File menu.
5. Click the close button and kill the notebook.
6. Reopen it as a help file using File→Open File→Help File.

   Alternatively, you can press Shift while choosing the file from File→Recent Files. Then, in the resulting

dialog, specify that you want to open the file as a help file.

Syntax of a Help File

Igor needs to be able to identify topics, subtopics, related topics declarations, and links in Igor help files. To do this it looks for certain rulers, text patterns and text formats described in **Creating Links** on page IV-242. You can get most of the required text formats by using the appropriate ruler from the Igor Help File Template file.

Igor considers a paragraph to be a help topic declaration if it starts with a bullet character followed by a tab and if the paragraph's ruler is named Topic. By convention, the Topic ruler's font is Geneva on Macintosh or Arial on Windows, its text size is 12 and its text style is bold-underlined. The bullet and tab characters should be plain, not bold or underlined.

The easiest way to create a new topic with the right formatting is to copy an existing topic and then modify it.

Once Igor finds a topic declaration, it scans the body of the topic. The body is all of the text until the next topic declaration, a related-topics declaration, or the end of the file. While scanning, it notes any subtopics.

Igor considers a paragraph to be a subtopic declaration if the name of the ruler governing the paragraph starts with "Subtopic". Thus if the ruler is named Subtopic or Subtopic+ or Subtopic2, the paragraph is a subtopic declaration. By convention, the Subtopic ruler's font is Geneva on Macintosh or Arial on Windows, its text size is 10 and its text style is bold and underlined. Text following the subtopic name that is not bold and underlined is not part of the subtopic name.

The easiest way to create a new subtopic with the right formatting is to copy an existing subtopic and then modify it.

Igor considers a paragraph to be a related-topics declaration if the ruler governing the paragraph is named RelatedTopics and if the paragraph starts with the text pattern "Related Topics:". When Igor sees this pattern it knows that this is the end of the current topic. The related-topics declaration is optional. Prior to Igor Pro 4, Igor displayed a list of related topics in the Igor Help Browser. Igor Pro no longer displays this list. The user can still click the links in the related topics paragraph to jump to the referenced topics.

Igor knows that it has hit the end of the current topic when it finds the related-topics declaration or when it finds a new topic declaration. In either case, it proceeds to compile the next topic. It continues compiling until it hits the end of the file.

When compiling the help file, Igor may encounter syntax that it can't understand. For example, if you have a related-topics declaration paragraph, Igor will expect the next paragraph to be a topic declaration. If it is not, Igor will stop the compilation and display an error dialog. You need to open the file as a notebook, fix the error, save and kill it and then reopen it as a help file.

Another error that is easy to make is to fail to use the plain text format for syntactic elements like bullet-tab, "Related Topics:" or the comma and space between related topics. If you run into a non-obvious compile error in a topic, subtopic or related topics declaration, recreate the declaration by copying from a working help file.

The help files supplied by WaveMetrics contain a large number of rulers to define various types of paragraphs such as topic paragraphs, subtopic paragraphs, related topic paragraphs, topic body paragraphs and so on. The Igor Help File Template contains many but not all of these rulers. If you find that you need to use a ruler that exists in a WaveMetrics help file but not in your help file then copy a paragraph governed by that ruler from the WaveMetrics help file and paste it into your file. This transfers the ruler to your file.

Creating Links

A link is text in an Igor help file that, when clicked, takes the user to some other place in the help. Igor considers any pure blue, underlined text to be a link. Pure blue means that the RGB value is (0, 0, 65535). By convention links use the Geneva font on Macintosh and the Arial font on Windows.

To create a link, select the text in the notebook that you are preparing to be a help file. Then choose Make Help Link from the Notebook menu. This sets the text format for the selected text to pure blue and underlined.

The link text refers to another place in the help using one of these forms:

- The name of a help topic (e.g., Command Window)
- The name of a help subtopic (e.g., History Area)
- A combined topic and subtopic (e.g., Command Window[History Area])

Use the combined form if there is a chance that the help topic or subtopic name by itself may be ambiguous. For example, to refer to the Preferences operation, use Operations[Preferences] rather than Preferences by itself.

When the user double-clicks a link, Igor performs the following search:

1. If the link is a topic name, Igor goes to that topic.
2. If the link is in topic[subtopic] form, Igor goes to that subtopic.
3. If steps 1 and 2 fail, Igor searches for a subtopic with the same name as the link. First, it searches for a subtopic in the current topic. If that fails, it searches for a subtopic in the current help file. If that fails, it searches for a subtopic in all help files.
4. If step 3 fails, Igor searches all help files in the Igor Pro 7 folder. If it finds the topic in a closed help file, it opens and displays it.
5. If step 4 fails, Igor searches all help files in the Igor Pro User Files folder. If it finds the topic in a closed help file, it opens and displays it.
6. If all of the above fail, Igor displays a dialog saying that the required help file is not available.

You can create a link in a help file that will open a Web page or FTP site in the user's Web or FTP browser. You do this by entering the Web or FTP URL in the help file while you are editing it as a notebook. The URL must appear in this format:

```
<http://www.wavemetrics.com>
<ftp://ftp.wavemetrics.com>
```

The URL must include the angle brackets and the "http://", "https://" or "ftp://" protocol specifier. Support for https was added in Igor Pro 7.02.

After entering the URL, select the entire URL, including the angle brackets, and choose Make Help Link from the notebook menu. Once the file is compiled and opened as a help file, clicking the link will open the user's Web or FTP browser and display the specified URL.

For any other kind of URL, such as sftp or mailto, use a notebook action that calls BrowseURL instead of a help link.

It is currently not possible make ordinary text into a Web or FTP link. The text must be an actual URL in the format shown above or you can insert a notebook action which brings up a web page using the **BrowseURL** operation on page V-45. See **Notebook Action Special Characters** on page III-14 for details.

Checking Links

You can tell Igor to check your help links as follows:

1. Open your Igor help file and compile it as a help file if necessary.
2. Activate your help window.
3. Right-click in the body of the help file and choose Check Help Links. Igor will check your links from where you clicked to the end of the file and note any problems by writing diagnostics to the history area of the command window.
4. When Igor finishes checking, if it found bad links, kill the help file and open it as a notebook.
5. Use the diagnostics that Igor wrote in the history to find and fix any link errors.
6. Save the notebook and kill it.
7. Open the notebook as a help file. Igor will compile it.
8. Repeat the check by going back to Step 1 until you have no bad links.

During this process, Igor searches for linked topics and subtopics in open and closed help files and opens any closed help file to which a link refers. If a link is not satisfied by an already open help file, Igor searches closed help files in:

- The Igor Pro 7 Folder and subfolders
- The Igor Pro User Files folder and subfolders
- Files and folders referenced by aliases or shortcuts in one of those folders

You can abort the check by pressing the **User Abort Key Combinations**.

The diagnostic that Igor writes to the history in case of a bad link is in the form:

```
Notebook $nb selection={(33,292), (33,334)} …
```

This is set up so that you can execute it to find the bad link. At this point, you have opened the help file as a notebook. Assuming that it is named Notebook0, execute

```
String/G nb = "Notebook0"
```

Now, you can execute the diagnostic commands to find the bad link and activate the notebook. Fix the bad link and then proceed to the next diagnostic. It is best to do this in reverse order, starting with the last diagnostic and cutting it from the history after fixing the problem.

If you press the Shift key while right-clicking a help window, you can choose Check Help Links in All Open Help Files. Then Igor checks all help links all help files open at that time. While checking a help file, Igor may open a previously unopened help file. Such newly opened help files are not checked. Only those help files open when you chose Check Help Links in All Open Help Files are checked. However, if you repeat the process, help files opened during the previous iteration are checked.

When fixing a bad link, check the following:

- A link is the name of a topic or subtopic in a currently open help file. Check spelling.
- There are no extraneous blue/underlined characters, such as tabs or spaces, before or after the link. (You can not identify the text format of spaces and tabs by looking at them. Check them by selecting them and then using the Set Text Format dialog.)
- There are no duplicate topics. If you specify a link in topic[subtopic] form and there are two topics with the same topic name, Igor may not find the subtopic.

Creating Formatted Text

The printf, sprintf, and fprintf operations print formatted text to Igor's history area, to a string variable or to a file respectively. The wfprintf operation prints formatted text based on data in waves to a file.

All of these operations are based on the C printf function which prints the contents of a variable number of string and numeric variables based on the contents of a format string. The format string can contain literal text and conversion specifications. Conversion specifications define how a variable is to be printed.

Here is a simple example:

```
printf "The minimum is %g and the maximum is %g\r", V_min, V_max
```

In this example, the format string is `"The minimum is %g and the maximum is %g\r"` which contains some literal text along with two conversion specifications — both of which are "`%g`"— and an escape code ("`\r`") indicating "carriage-return". If we assume that the Igor variable V_min = .123 and V_max = .567, this would print the following to Igor's history area:

```
The minimum is .123 and the maximum is .567
```

We could print this output to an Igor string variable or to a file instead of to the history using the **sprintf** (see page V-771) or **fprintf** (see page V-223) operations.

Printf Operation

The syntax of the printf operation is:

```
printf format [, parameter [, parameter ]. . .]
```

where *format* is the format string containing literal text or format specifications. The number and type of parameters depends on the number and type of format specifications in the format string. The parameters, if any, can be literal numbers, numeric variables, numeric expressions, literal strings, string variables or string expressions.

The conversion specifications are very flexible and make printf a powerful tool. They can also be quite involved. The simplest specifications are:

Specification	What It Does
%g	Converts a number to text using integer, floating point or exponential notation depending on the number's magnitude.
%e	Converts a number to text using exponential notation.
%f	Converts a number to text using floating point notation.
%d	Converts a number to text using integer notation.
%s	Converts a string to text.

Here are some examples:

```
printf "%g, %g, %g\r", PI, 6.022e23, 1.602e-19
```

prints:

```
3.14159, 6.022e+23, 1.602e-19
```

```
printf "%e, %e, %e\r", PI, 6.022e23, 1.602e-19
```

prints:

```
3.141593e+00, 6.022000e+23, 1.602000e-19
```

```
printf "%f, %f, %f\r", PI, 6.022e23, 1.602e-19
```

prints:

```
3.141593, 602200000000000027200000.000000, 0.000000
```

```
printf "%d, %d, %d\r", PI, 6.022e23, 1.602e-19
```

prints:

```
3, 9223372036854775807, 0
```

```
printf "%s, %s\r", "Hello, world", "The time is " + Time()
```

prints:

```
Hello, world, The time is 11:43:40 AM
```

Note that the output for 6.022e23 when printed using the %d conversion specification is wrong. This is because 6.022e23 is too big a number to represent as an 64-bit integer.

If you want better control of the output format, you need to know more about conversion specifications. It gets quite involved. See the **printf** operation on page V-653.

sprintf Operation

The sprintf operation is very similar to printf except that it prints to a string variable instead of to Igor's history. The syntax of the sprintf operation is:

```
sprintf stringVariable, format [, parameter [, parameter ]. . .]
```

where *stringVariable* is the name of the string variable to print to and the remaining parameters are as for printf. sprintf is useful for generating text to use as prompts in macros, in axis labels and in annotations.

fprintf Operation

The fprintf operation is very similar to printf except that it prints to a file instead of to Igor's history. The syntax of the fprintf operation is:

```
fprintf variable, format [, parameter [, parameter ]. . .]
```

where *variable* is the name of a numeric variable containing the file reference number for the file to print to and the remaining parameters are as for printf. You get the file reference number using the Open operation, described under **Open and Close Operations** on page IV-185.

For debugging purposes, if you specify 1 for the file reference number, Igor prints to the history area instead of to a file, as if you used printf instead of fprintf.

wfprintf Operation

The wfprintf operation is similar to printf except that it prints the contents of one to 100 waves to a file. The syntax of the wfprintf operation is:

```
wfprintf variable, format [/R=(start,end)] wavelist
```

variable is the name of a numeric variable containing the file reference number for the file to print to.

Unlike printf, which rounds, wfprintf converts floating point values to integers by truncating, if you use an integer conversion specification such as "%d".

Example Using fprintf and wfprintf

Here is an example of a command sequence that creates some waves and put values into them and then writes them to an output file with column headers.

```
Make/N=25 wave1, wave2, wave3
wave1 = 100+x; wave2 = 200+x; wave3 = 300+x
Variable f1
Open f1
fprintf f1, "wave1, wave2, wave3\r"
wfprintf f1, "%g, %g, %g\r" wave1, wave2, wave3
Close f1
```

This generates a comma delimited file. To generate a tab delimited file, use:

```
fprintf f1, "wave1\twave2\twave3\r"
wfprintf f1, "%g\t%g\t%g\r" wave1, wave2, wave3
```

Since tab-delimited is the default format for wfprintf, this last command is equivalent to:

```
wfprintf f1, "" wave1, wave2, wave3
```

Client/Server Overview

An application can interact with other software as a server or as a client.

A server accepts commands and data from a client and returns results to the client.

A client sends commands and data to a server program and receives results from the server.

For the Macintosh, see **Apple Events** on page IV-247 for server information and **AppleScript** on page IV-249 for client capabilities.

For Windows, see **ActiveX Automation** on page IV-250. Igor can play the role of an Automation server but not an Automation client. However it is possible to generate script files that allow Igor to indirectly play the role of client.

On Windows, Igor also supports Dynamic Data Exchange (DDE) and can be a DDE server or DDE client. Because DDE is obsolescent and being phased out by Microsoft, new programming should use ActiveX automation. Igor's support for DDE is described in the Obsolete Topics help file.

Apple Events

This topic is of interest to *Macintosh* programmers. Windows users should see the section for **ActiveX Automation** on page IV-250.

This topic contains information for Igor users who wish to control Igor from other programs (e.g., AppleScript). It also contains information useful to people who are writing their own programs and wish to use Igor Pro as a computing or graphing engine.

There is also a mechanism that allows Igor to act like a controller and initiate Apple event communication with other programs. See **AppleScript** on page IV-249.

Apple Event Capabilities

Igor Pro supports the following Apple events:

Event	Suite	Action
Open Application	Required	Basically a nop; don't use.
Open Document	Required	Loads an experiment.
Print Document	Required	NA; don't use.
Quit Application	Required	Quits.
Close	Core	Acts on experiment, window or PPC port.
Save	Core	Acts on experiment only.
Open	Core	NA; don't use.
Do Script	Misc	Executes commands; can return ASCII results.
Eval Expression	Misc	Same as Do Script; obsolete but included for compatibility.

Apple Events — Basic Scenario

You use the Open Document event to cause Igor to load an experiment with whatever goodies you find useful. You then use the Do Script or Eval Expression events to send commands to Igor for execution and to retrieve results. To get data into Igor you write files and then send commands to Igor to load the data. To get data waves from Igor you do the reverse. To get graphics, you send commands to Igor that cause it to write a graphics file that you can read. You may then close the experiment and start over with a new one. You will not likely use the Save event.

Apple Events — Obtaining Results from Igor

To return information from Igor, you will need to embed special commands in the script you send to Igor for execution. When Igor encounters these commands, it appends results to a packet that is returned to your application after script execution ends. The special commands are variations on the standard Igor commands FBinWrite and fprintf. Both of these commands take a file reference number as a parameter. If the magic value zero is used rather than a real file reference number, then the data that would normally be written to a file is appended to the result packet.

As far as Igor is concerned, there is no difference between the Do Script and Eval Expression events. However, old applications may expect results from Eval Expression and not from Do Script.

To use waves and graphics with Apple events, you will need to write or read the data via standard Igor files. For example, you might include

```
SavePICT /E=-8 /P=MyPath as "Graphics.pdf"
```

in a script that you send to Igor for execution. You could then read the file in your application.

Apple Event Details

This information is intended for programmers familiar with Apple events terminology.

Some of the following events can act on experiments or windows.

To specify an experiment, use object class cDocument (`'docu'`) and specify either formAbsolutePosition with index=1 or formName with name=*name of experiment*.

To specify a window, use object class cWindow (`'cwin'`) and either formAbsolutePosition or formName with name=*title of window*.

Event	Class	Code	Action
Open Application	`'aevt'`	`'oapp'`	Basically a nop; don't use.
Open Document	`'aevt'`	`'odoc'`	Loads an experiment. Direct object is assumed to be coercible to a File System Spec record.
Print Document	`'aevt'`	`'pdoc'`	NA; don't use.
Quit Application	`'aevt'`	`'quit'`	Quits the program. If the experiment was modified, then Igor attempts to interact with the user to get save/no save directions. If interaction is not allowed, then an error is returned and nothing is done. To prevent errors, send the close event with appropriate save options prior to sending quit.
Close	`'core'`	`'clos'`	Acts on an experiment or window. For a window, the save/no save/ask optional parameter (keyAESaveOptions) is allowed and refers to making/replacing a recreation macro. For a document (experiment), keyAESaveOptions is allowed and an additional optional parameter keyAEDestination my be used to specify where to save (must be coercible to a FSS). If this is not given and the experiment is untitled and if an attempt to interact with the user fails then the experiment is not saved and an error (such as errAENoUserInteraction) is returned. Note that if the optional destination is given then the save options are ignored (why give a destination and then say no save?).
Save	`'core'`	`'save'`	Acts on experiment only. Takes same optional destination parameters as Close. A save with a destination is the same as a Save as.

Event	Class	Code	Action
Do Script	'misc'	'dosc'	Same as Eval Expression.
Eval Expression	'aevt'	'eval'	Executes commands. Acts just as if commands had been typed into the command line except the individual command lines are preceded by a percent symbol rather than the usual bullet symbol. Also, errors are returned in the error reply parameter of the event rather than putting up a dialog. **Note**: You can suppress history logging by executing the command, "Silent 2", and you can turn it back on by executing "Silent 3". Direct parameter must be text and not a file. Text can be of any length. You can return a string containing results by using the fprintf command with a file reference number of zero.

AppleScript

This topic is of interest to *Macintosh* programmers. Windows users should see the section for **ActiveX Automation** on page IV-250.

Igor supports the creation and execution of simple AppleScripts in order to send commands to other programs.

To execute an AppleScript program, you first compose it in a string and then pass it to the ExecuteScriptText operation, which in turn passes the text to Apple's scripting module for compilation and execution. The result, which might be an error message, is placed in a string variable named S_value. Igor does not save the compiled script so every time you call ExecuteScriptText your script will have to be recompiled. See the **ExecuteScriptText** operation on page V-177 for additional details.

The documentation for the **ExecuteScriptText** operation (page V-177) includes an example that shows how to execute a Unix command.

Because there is no easy way to edit a script or to see where errors occur, you should first test your script using Apple's Script Editor application.

You can use "Silent 2" to prevent commands your script sends to Igor from being placed in the history area.

You can send commands to Igor without using the tell keyword.

You should check your quoting carefully. Your text must be quoted both for Igor and for Apple's scripting system. For example,

```
ExecuteScriptText "Do Script \"Print \\\"hello\\\"\""
```

You should compose scripts in string variables one line at a time to improve readability.

If an error occurs that you can't figure out, print the string, copy from the history and paste into a Script Editor for debugging.

If the script returns a text return value, it will be quoted within the S_value string.

Don't forget to include the carriage return escape code, \r, at the end of each line of a multiline script.

The first time you call this routine, it may take an extra long time while the Mac OS loads the scripting modules.

Executing Unix Commands on Mac OS X

On Mac OS X, you can use AppleScript to send a command to the Unix shell. Here is a function that illustrates this:

```
Function/S ExecuteUnixShellCommand(uCommand, printCommandInHistory,
printResultInHistory)
	String uCommand					// Unix command to execute
	Variable printCommandInHistory
	Variable printResultInHistory

	if (printCommandInHistory)
		printf "Unix command: %s\r", uCommand
	endif

	String cmd
	sprintf cmd, "do shell script \"%s\"", uCommand
	ExecuteScriptText cmd

	if (printResultInHistory)
		Print S_value
	endif

	return S_value
End
```

You can test the function with this command:

```
ExecuteUnixShellCommand("ls", 1, 1)
```

Life is a bit more complicated if the command that you want to execute contains spaces or other nonstandard Unix command characters. For example, imagine that you want to execute this:

```
ls /System/Library/Image Capture
```

These commands will not work because of the space in the command:

```
String unixCmd = "ls /System/Library/Image Capture"
ExecuteUnixShellCommand(unixCmd, 1, 1)
```

You need to quote the entire Unix command. In order to do this such that the quotes will make it through Igor's parser and AppleScript's parser, you must do this:

```
String unixCmd = "ls \\\"/System/Library/Image Capture\\\""
ExecuteUnixShellCommand(unixCmd, 1, 1)
```

Igor's parser converts \\ to \ and \" to ", so AppleScript sees this:

```
"ls \"/System/Library/Image Capture\""
```

AppleScript's parser converts \" to " so Unix sees this:

```
ls "/System/Library/Image Capture"
```

ActiveX Automation

ActiveX Automation, often called just Automation, is Microsoft's technology for allowing one program to control another. The program that does the controlling is called the Automation client. The program that is controlled is called the Automation Server. The client initiates things by making calls to the server which carries out the requested actions and returns results.

Automation client programs are most often written in Visual Basic or C#. They can also be written in C++ and other programming languages, and in various scripting languages such as VBScript, JavaScript, Perl, Python and so on.

Igor can play the role of Automation Server. If you want to write an client program to drive Igor, see "Automation Server Overview" in the "Automation Server" help file in "\Igor Pro 7 Folder\Miscellaneous\Windows Automation".

Igor Pro does not directly support playing the role of Automation client. However, it is possible to write an Igor program which generates a script file which can act like an Automation client. For an example, choose File→Example Experiments→Programming→CallMicrosoftWord.

Calling Igor from Scripts

You can call Igor from shell scripts, batch files, Apple Script, and the Macintosh terminal window using an operation-like syntax. You can also use this feature to register an Igor license.

The syntax for calling Igor is:

```
<IGOR> [/I /Q /X /Y /N /Automation]  [pathToFileOrCommands] [pathToFile] ...
```

```
<IGOR> [/I /N /Automation]  [pathToFileOrCommands] [pathToFile] ...
```

```
<IGOR> [/I /Q /X /Automation] "commands"
```

```
<IGOR> /SN=num /KEY="key" /NAME="name" [/ORG="org" /QUIT]
```

where `<IGOR>` is the full path to the Igor executable file.

On Windows, the Igor executable file resides in a folder within the Igor Pro folder. The full path will be something like:

```
"C:\Program Files\WaveMetrics\IgorBinaries_x64\Igor Pro 7 Folder\Igor64.exe"
```

On Macintosh, the Igor application is an "application bundle" and the actual executable file is inside the bundle. The full path will be something like:

```
'/Applications/Igor Pro 7 Folder/Igor64.app/Contents/MacOS/Igor64'
```

In the following discussions, `<IGOR>` means "the full path to the Igor executable file".

Parameters

All parameters are optional. If you omit all parameters, including just the full path to the Igor executable, a new instance of Igor is launched.

The usual parameter is a file for Igor to open. It is recommended that both the path and the path to the file parameter be enclosed in quotes.

You can open multiple files by using a space between one quoted file path and the next.

With the /X flag, only one parameter is allowed and it is interpreted as an Igor command.

Flags

When you specify a flag, you can use a - instead of /. For example, you can write /Q or -Q.

/Automation	This flag is supported on Windows only. The Windows OS uses it when launching Igor Pro as an ActiveX Automation server. It is not intended for use in batch files.
/I	Launches a new instance of Igor if one would otherwise not be launched. See ***Details*** for a discussion of instances.
/KEY="*key*"	Specifies the license activation key when registering a license. For example: `/KEY="ABCD-EFGH-IJKL-MNOP-QRST-UVWX-Y"` Do not omit the quotes, or it will fail.
/N	Forces the current experiment to be closed without saving if any of the file parameters are an experiment file. To save a currently open experiment, use: `<IGOR> /X "SaveExperiment"`
/NAME="*name*"	Specifies the name of the licensed user when registering a license. A name is required when registering.

/ORG="*org*" Specifies the optional name of the licensed organization when registering a license. /ORG is optional and defaults to "".

/Q Prevents the command from being displayed in Igor's command line as it is executing.

/QUIT Quits Igor Pro after entering license information when used with /SN, /KEY, and /NAME. Otherwise /QUIT is ignored.

To quit Igor Pro, use:

```
<IGOR> /X "Quit/N"
```

/SN=*num* Specifies the license serial number when registering a license.

/X Executes the commands in the parameter. Only one parameter is allowed with /X. Use semicolons to separate Igor commands within the parameter.

Details

If an existing instance of Igor is running, the command is sent to the existing instance if you omit the /I flag and you include /X, /SN, or a path to a file. Otherwise, a new instance of Igor is launched.

Registering a License

You can register an Igor license using the /SN, /KEY, and /NAME flags. All of these flags must be present to successfully register a license. The optional /ORG parameter defaults to "".

These batch file commands register Igor Pro with the given serial number and license activation key:

```
<IGOR> /SN=1234567 /KEY="ABCD-EFGH-IJKL-MNOP-QRST-UVWX-Y" /NAME="Jack" /ORG="Acme Scientific" /QUIT
```

Network Communication

The following sections contain material related to the network communication and Internet-related capabilities of Igor Pro:

URLs on page IV-252

Safe Handling of Passwords on page IV-254

Network Timeouts and Aborts on page IV-255

Network Connections From Multiple Threads on page IV-255

File Transfer Protocol (FTP) on page IV-257

Hypertext Transfer Protocol (HTTP) on page IV-261

URLs

URLs, or Uniform Resource Locators, are compact strings that represent a resource available via the Internet. The description of the URL standard is described in RFC1738 (http://www.rfc-editor.org/rfc/rfc1738.txt) and updated in RFC3986 (http://www.rfc-editor.org/rfc/rfc3986.txt).

Each URL is composed of several different parts, most of which are optional:

```
<scheme>://<username>:<password>@<host>:<port>/<path>?<query>
```

Some examples of valid URLs are:

```
http://www.example.com
http://www.example.com/afolder?key1=45&key2=66
http://myusername:Passw0rD@www.example.com:8010/index.html
ftp://ftp.wavemetrics.com
file:///C:\\Data\\Trial1\\control.ibw (on Windows only)
file:///Users/bob/Data/Trial1/control.ibw (on Macintosh only)
```

For most operations and functions that take a *urlStr* parameter, only the scheme and host parts of the URL are required. See the **Supported Network Schemes** section for information on which schemes are sup-

ported by which operations and functions, and which port is used by default if it is not provided as part of the URL.

Usernames and Passwords

You can provide a username and password as part of the URL. However authentication credentials may not be supported by all schemes (such as file://). Some operations allow you to provide a username and password by using a flag, such as the /U and /W flags with **FTPDownload** or the /AUTH flag with **URLRequest**.

If a URL contains a username and password in the URL and the authentication flags are also used, the values specified in the flags override values provided in the URL.

If you do not provide a username and password as part of the URL, and you do not use the authentication flags, then no authentication is attempted. An exception to this rule is that the FTP operations will login to the FTP server using "anonymous" as the username and a generic email address as the password.

If either the username or password contains special or reserved characters, those characters must be percent-encoded.

Supported Network Schemes

Different operations and functions support different schemes:

Operation	Supported Schemes	Default Port
FetchURL and **URLRequest**	http	80
	https	443
	ftp	21
	file	Not applicable
FTP operations*	ftp	21

* Includes **FTPUpload**, **FTPDownload**, **FTPDelete**, and **FTPCreateDirectory**.

Percent Encoding

Percent encoding is a way to encode characters in URLs that would otherwise have a special meaning or could be misinterpreted by servers. For example, a space character in a URL is encoded as "%20" using a percent character followed by the hex code for a space in the ASCII character set.

Most URLs contain only the letters A-Z and a-z, the digits 0-9, and a few other characters such as the underscore (_), hyphen (-), period (.), and tilde (~).

A URL may also contain "reserved characters" that may have special meaning depending on the way that they are used. Every URL contains the reserved characters ":" and "/" and may also contain one or more of the following reserved characters: !*'();@&=+$,?#[].

All operations and functions provided by Igor Pro that accept a URL string parameter expect that the URL has already been percent-encoded as necessary.

In most cases you don't need to worry about percent encoding because most URLs don't use reserved characters except for their special meaning. If you need to use a reserved character in a way that differs from the character's special meaning, you must percent-encode the character. You can use the **URLEncode** function for this purpose.

It is important that you not pass your entire URL to URLEncode to be encoded because that URL will not be understood by a server. URLEncode percent-encodes all reserved characters in the string you pass to it, because it cannot distinguish between reserved characters used for their special meaning and reserved

characters used outside of their special meaning. Instead, you must pass each piece of the URL through URLEncode so that the final URL uses the correct syntax.

As an example, we'll use URLEncode to properly encode a URL that contains the following parts:

Part Name	Example
Scheme	http
Username	A. MacGyver
Password	yj@!2M
Host	www.example.com
Path	/tape/duct
Query	discount=10%&color=red

Without any percent-encoding, the URL is:

```
http://A. MacGyver:yj@!2M@www.example.com/tape/duct?discount=10%&color=red
```

If this URL were passed to **FetchURL**, the result would be an error because the URL contains several reserved characters that are not intended to be used in their standard way. For example, the "@" character indicates the separation between the username:password information and the start of the host name, but in this case the password itself also contains the "@" character. In addition, the "%" character is typically used to indicate that the next two characters represent a percent-encoded character, but in this example it is also part of the query. Finally, the username contains a space character. The space character is not technically a reserved character, but should be percent-encoded to ensure that it is handled correctly.

The following table shows the values of the parts of the URL that need to be percent-encoded by passing them through the URLEncode function:

Part Name	Encoded Value
Username	A%2E%20MacGyver
Password	yj%40%212M
Host	www.example.com
Path	/tape/duct
Query	discount=10%25&color=red

The properly percent-encoded URL is:

```
http://A%2E%20MacGyver:yj%40%212M@www.example.com/tape/duct?discount=10%25&color=red
```

For keyword-value pairs that make up the query part, each keyword and value must be percent-encoded separately because the "=" character that separates the key from the value and the "&" character that separates the pairs in the list must not be percent-encoded.

For more information on percent-encoding and reserved characters, see http://en.wikipedia.org/wiki/Percent-encoding.

Safe Handling of Passwords

Some operations and functions support the use of a username and password when making a network connection. If you use sensitive passwords you must take certain precautions to prevent them from being accidentally revealed.

1. Always use the /V=0 flag when using a username or password with the /U (username) and /W (pass-

word) flags or the /AUTH flag. Otherwise, the debugging information that is printed to the history area will contain those values and anyone who sees the experiment could see them.

2. Do not hard code username or password values into procedures, since anyone with access to the procedure file could read them.
3. Do not store username or password values in global variables. Since global variables are saved with an experiment, if someone else had access to your experiment they could see this information.

Here is an example of how a username and sensitive password can be used in a secure manner:

```
Function SafeLogin()
   String username = ""
   String password = ""
   Prompt username, "Username"
   Prompt password, "Password"
   DoPrompt "Enter username and password", username, password
   if (V_flag == 1)
      // User hit cancel button, so do nothing.
      return 0
   endif

   // Percent-encode in case username and password contain reserved characters.
   String encodedUser = URLEncode(username)
   String encodedPass = URLEncode(password)

   String theURL
   sprintf theURL, "http://%s:%s@www.example.com", encodedUser, encodedPass
   String response = FetchURL(theURL)
   // NOTE: For FTP operations and URLRequest, make sure to use /V=0 so that
   // the username and password are not printed to the history.

   return 0
End
```

Note that the user is prompted to provide the username and password when the function is called and that only local string variables are used to store the username and password. The values in those string variables are not stored once the function is done executing.

Note also that the password is not hidden during entry in the dialog. Igor currently does not provide a way to do this.

Network Timeouts and Aborts

Some network calls may return an error code to Igor if they timeout. Depending on the specific operation or function, there can be a number of causes for a timeout.

If a network connection cannot be made after a period of time it will timeout. The amount of time allowed for a connection to be established is dependent on several factors.

You can always abort a network operation or function by pressing the **User Abort Key Combinations**.

Network Connections From Multiple Threads

All network-related operations and functions are thread-safe, which means that they can be called from multiple preemptive threads at the same time. This capability can be useful when:

- You want to retrieve information from several different URLs as quickly as possible.
- You want to do a long download or other operation in the background to avoid tieing Igor up.

The following example illustrates the first of these cases. It uses **FetchURL** to retrieve a list of the most frequently downloaded books from the Project Gutenberg web site. It then uses FetchURL to download the entire text of the top four books and prints the number of bytes in each.

```
ThreadSafe Function GetThePage(url)
   String url

   String response = FetchURL(url)
   return strlen(response)
End

Function ListGutenbergTopBooks()
   String topBooksURL = "http://www.gutenberg.org/browse/scores/top"
   String baseURL = "http://www.gutenberg.org/files/"

   // Get the contents of the page.
   String response = FetchURL(topBooksURL)
   Variable error = GetRTError(1)
   if (error || numtype(strlen(response)) != 0)
      Print "Error getting the list of most popular books."
      return 0
   endif

   String topBooksHTML = response

   // Remove all line endings.
   topBooksHTML = ReplaceString("\n", topBooksHTML, "")
   topBooksHTML = ReplaceString("\r", topBooksHTML, "")

   // Parse the page to get the section of the page
   // with the list of the most popular books from yesterday.
   // This could break if the format of the web page changes.
   String regExp = "(?i)<h2 id=\"books-last1\">.*?<ol>(.*?)</ol>"
   String topYesterdayHTML = ""
   SplitString/E=regExp topBooksHTML, topYesterdayHTML
   if (V_flag != 1)
      Print "Error parsing the top 100 books section."
      return 0
   endif

   // Replace the line endings.
   topYesterdayHTML = ReplaceString("</li><li>", topYesterdayHTML, "\r")

   // Create a wave to store text info about the top four books.
   Variable numBooksToUse = 4
   Make/O/T/N=(numBooksToUse, 2) topBooksInfo

   Make/O/N=(numBooksToUse) byteCounts

   Variable n
   String bookNumStr
   Variable bookNum
   String titleAuthor
   String thisLine
   Variable pos
   String bookURL = ""
   regExp = "(?i)a href=\".*?(\d+)\">(.+?)</a>"
   for (n=0; n<numBooksToUse; n+=1)
      // For each book we're going to look at, get the
      // partial URL and the title/author text.
      thisLine = StringFromList(n, topYesterdayHTML, "\r")
```

```
		SplitString/E=regExp thisLine, bookNumStr, titleAuthor
		if (V_flag != 2)
			Print "Error parsing the URL and title/author information."
			return 0
		endif

		// Remove the (###) stuff at the end of titleAuthor if it's there.
		pos = strsearch(titleAuthor, "(", 0)
		if (pos > 0)
			titleAuthor = titleAuthor[0, pos - 1]
		endif

		bookNum = str2num(bookNumStr)

		// Store the information about the book in the text wave.
		sprintf bookURL, "%s%d/%d.txt", baseURL, bookNum, bookNum
		topBooksInfo[n][0] = bookURL
		topBooksInfo[n][1] = titleAuthor
	endfor

	// Download each book (using multiple threads if possible)
	// and count the number of bytes in each.
	MultiThread byteCounts = GetThePage(topBooksInfo[p][0])

	// Print the results.
	Print "The top four books by download from yesterday are:"
	for (n=0; n<numBooksToUse; n+=1)
		Printf "%s (%d bytes)\r", topBooksInfo[n][1], byteCounts[n]
	endfor
End
```

Here is an example of what the output was when this help file was written:

The top four books by download from yesterday are:

```
Ulysses by James Joyce (1573044 bytes)
Alice's Adventures in Wonderland by Lewis Carroll (167529 bytes)
Piper in the Woods by Philip K. Dick (62214 bytes)
Pride and Prejudice by Jane Austen (704160 bytes)
```

File Transfer Protocol (FTP)

The **FTPDownload**, **FTPUpload**, **FTPDelete**, and **FTPCreateDirectory** operations support simple transfers of files and directories over the Internet.

Since Igor's SaveNotebook operation can generate HTML files from notebooks, it is possible to write an Igor procedure that downloads data, analyzes it, graphs it, and uploads an HTML file to a directory used by a Web server. You can then use the BrowseURL operation to verify that everything worked as expected. For a demo of some of these features, choose File→Example Experiments→Feature Demos→Web Page Demo.

FTP Limitations

All FTP operations run "synchronously". This means that, if the operation executes in the main thread, Igor can not do anything else. However, it is possible to perform these operations using an Igor preemptive thread so that they execute in the background and you can continue to use Igor for other purposes. For more information, see **Network Connections From Multiple Threads** on page IV-255.

Igor does not currently provide any way for the user to browse the remote server from within Igor itself.

Igor does not provide any secure way to store passwords. Consequently, you should not use Igor for FTP in situations where tight security is required. See **Safe Handling of Passwords** on page IV-254 for an example of how to securely prompt the user for a password.

Igor does not provide any support for using proxy servers. Proxy servers are security devices that stand between the user and the Internet and permit some traffic while prohibiting other traffic. If your site uses a proxy server, FTP operations may fail. Your network administrator may be able to provide a solution.

Igor does not include operations for listing a server directory or changing its current directory.

Downloading a File

The following function transfers a file from an FTP server to the local hard disk:

```
Function DemoFTPDownload()
   String url = "ftp://ftp.wavemetrics.net/welcome.msg"
   String localFolder = SpecialDirPath("Desktop",0,0,0)
   String localPath = localFolder + "DemoFTPDownloadFile.txt"
   FTPDownload/U="anonymous"/W="password" url, localPath
End
```

The output directory must already exist on the local hard disk. The target file may or may not exist on the local hard disk. If it does not exist, the FTPDownload command creates it. If it does exist, FTPDownload asks if you want to overwrite it. To overwrite it without being asked, use the /O flag.

Warning: If you elect to overwrite it, all previous contents of the local target file are obliterated.

FTPDownload presents a dialog asking you to specify the local file name and location in the following cases:

1. You use the /I (interactive) flag.
2. The parent directory specified by the local path does not exist.
3. The specified local file exists and you do not use the /O (overwrite) flag.

Downloading a Directory

The following function transfers a directory from an FTP server to the local hard disk:

```
Function DemoFTPDownloadDirectory()
   String url = "ftp://ftp.wavemetrics.net/Utilities"
   String localFolder = SpecialDirPath("Desktop",0,0,0)
   String localPath = localFolder + "DemoFTPDownloadDirectory"
   FTPDownload/D/U="anonymous"/W="password" url, localPath
End
```

The /D flag specifies that you are transferring a directory.

The output directory may or may not already exist on the local hard disk. If it does not exist, the FTPDownload command creates it. If it does exist, FTPDownload asks if you want to overwrite it. To overwrite it without being asked, use the /O flag.

Warning: If you elect to overwrite it, all previous contents of the local directory are obliterated.

If the local path that you specify ends with a colon or backslash, FTPDownload presents a dialog asking you to specify the local directory because it is looking for the name of the directory to be created on the local hard disk.

FTPDownload presents a dialog asking you to specify the local directory in the following cases:

1. You use the /I (interactive) flag.
2. The parent directory specified by the local path does not exist.
3. The specified directory (DemoFTPDownloadFolder in the example above) exists and you have not used the /O (overwrite) flag.
4. FTPDownload gets an error when it tries to create the specified directory. This could happen, for example, if you don't have write privileges for the parent directory.

Uploading a File

The following function uploads a file to an FTP server:

```
Function DemoFTPUploadFile()
   String url = "ftp://ftp.wavemetrics.com/pub"
   String localFolder = SpecialDirPath("Desktop",0,0,0)
   String localPath = localFolder + "DemoFTPUploadFile.txt"
   FTPUpload/U="username"/W="password" url, localPath
End
```

To successfully execute this, you need a real user name and a real password.

Note: The /O flag has no effect on the FTPUpload operation when uploading a file. FTPUpload *always* overwrites an existing server file, whether /O is used or not.

Warning: If you overwrite a server file, all previous contents of the file are obliterated.

To overwrite an existing file on the server, you must have permission to delete files on that server. The server administrator determines what permission a particular user has.

FTPUpload presents a dialog asking you to specify the local file in the following cases:

1. You use the /I (interactive) flag.
2. The local parent directory or the local file does not exist.

Uploading a Directory

The following function uploads a directory to an FTP server:

```
Function DemoFTPUploadDirectory()
   String url = "ftp://ftp.wavemetrics.com/pub"
   String localFolder = SpecialDirPath("Desktop",0,0,0)
   String localPath = localFolder + "DemoFTPUploadDirectory"
   FTPUpload/D/U="username"/W="password" url, localPath
End
```

To successfully execute this, you need a real user name and a real password. Also, the server would have to allow uploading directories.

Note: FTPUpload *always* overwrites an existing server directory, whether /O is used or not.

Warning: If you omit /O or specify /O or /O=1, all previous contents of the directory are obliterated.

If you specify /O=2, FTPUpload performs a merge of the directory contents. This means that files and directories in the source overwrite files and directories on the server that have the same name, but files and directories on the server whose names do not conflict with those in the source directory are not modified.

To overwrite an existing directory on the server, you must have permission to delete directories on that server. The server administrator determines what permission a particular user has.

If the local path that you specify ends with a colon or backslash, FTPUpload presents a dialog asking you to specify the local directory because it is looking for the name of the directory to be uploaded.

FTPUpload presents a dialog asking you to specify the local directory in the following cases:

1. You use the /I (interactive) flag.
2. The specified directory or any of its parents do not exist.

If you don't have permission to remove and to create directories on the server, FTPUpload will fail and return an error.

Creating a Directory

The **FTPCreateDirectory** operation creates a new directory on an FTP server.

If the directory already exists on the server, the operation does nothing. This is not treated as an error, though the V_Flag output variable is set to -1 to indicate that the directory already existed.

If you don't have permission to create directories on the server, FTPCreateDirectory fails and returns an error.

Deleting a Directory

The **FTPDelete** operation with the /D flag deletes a directory on an FTP server.

If you don't have permission to delete directories on the server, or if the specified directory does not exist on the server, FTPDelete fails and returns an error.

FTP Transfer Types

The FTP protocol supports two types of transfers: image and ASCII. Image transfer is appropriate for binary files. ASCII transfer is appropriate for text files.

In an image transfer, also called a binary transfer, the data on the receiving end will be a replica of the data on the sending end. In an ASCII transfer, the receiving FTP agent changes line terminators to match the local convention. On Macintosh and Unix, the conventional line terminator is linefeed (LF, ASCII code 0x0A). On Windows, it is carriage-return plus linefeed (CR+LF, ASCII code 0x0D + ASCII code 0x0A).

If you transfer a text file using an image transfer, the file may not use the local conventional line terminator, but the data remains intact. Igor Pro can display text files that use any of the three conventional line terminators, but some other programs, especially older programs, may display the text incorrectly.

On the other hand, if you transfer a binary file, such as an Igor experiment file, using an ASCII transfer, the file will almost certainly be corrupted. The receiving FTP agent will convert any byte that happens to have the value 0x0D to 0x0A or vice versa. If the local convention calls for CRLF, then a single byte 0x0D will be changed to two bytes, 0x0D0A. In either case, the file will become unusable.

FTP Troubleshooting

FTP involves a lot of hardware and software on both ends and a network in between. This provides ample opportunity for errors.

Here are some tips if you experience errors using the FTP operations.

1. Use an FTP client or web browser to connect to the FTP site. This confirms that your network is operating, the FTP server is operating, and that you are using the correct URL.
2. Use an FTP client or web browser to verify that the user name and password that you are using is correct or that the server allows anonymous FTP access.

   Many web browser accept URLs of the form:

   ```
   ftp://username:password@ftp.example.com
   ```

   However the password is not transferred securely.
3. Use an FTP client or web browser to verify that the directory structure of the FTP server is what you think it is.
4. Using an FTP client or web browser, do the operation that you are attempting to do with Igor. This verifies that you have sufficient permissions on the server.
5. Use /V=7 to tell the Igor operation to display status information in the history area.
6. Try the simplest transfer you can. For example, try to download a single file that you know exists on the server.
7. If you have access to the FTP server, examine the FTP server log for clues.

Hypertext Transfer Protocol (HTTP)

The **FetchURL** function supports simple URL requests over the Internet from web or FTP servers and to local files. For example, you can use FetchURL to get the source code of a web page in text form, and then process the text to extract specific information from the response.

The **URLRequest** operation supports both simple URL requests and more complicated requests such as using the http POST, PUT, and DELETE methods. It also provides experimental support for using a proxy server.

HTTP Limitations

At this time, **FetchURL** and **BrowseURL** routines work with the HTTP protocol.

Currently not supported are features such as using network proxy servers, using the HTTP POST method to submit forms and upload files to a web server, and making secure network connections using the Secure Socket Layer (SSL) protocol.

Downloading a Web Page Via HTTP

This example uses FetchURL to download the contents of the WaveMetrics home page into a string, and then counts the number of times that the string "Igor" occurs in the text of the page.

```
Function DownloadWebPageExample()
   String webPageText = FetchURL("http://www.wavemetrics.com")
   if (numtype(strlen(webPageText)) == 2)
      Print "There was an error while downloading the web page."
   endif
   Variable count, pos
   do
      pos = strsearch(webPageText, "Igor", pos, 2)
      if (pos == -1)
         break    // No more occurrences of "Igor"
      else
         pos += 1
         count += 1
      endif
   while (1)
   Printf "The text \"Igor\" was found %d times on the web page.\r", count
End
```

Downloading a File Via HTTP

This example uses FetchURL to download a file from a web server. Because FetchURL does not support storing the downloaded data into a file directly, we store the data in memory and then use Igor to write that data to a file on disk.

Though the example uses a URL that begins with http://, FetchURL also supports https://, ftp:// and file://. You could use the code below with a different URL to download a file from an FTP server or even to access a local on-disk file.

```
Function DownloadWebFileExample()
   String url = "http://www.wavemetrics.net/IgorManual.zip"

   // Based on the URL, determine what the destination
   // file name should be. This will be the default in the
   // Save As... dialog.
   String urlStrParam = RemoveEnding(url, "/")
   Variable parts = ItemsInList(urlStrParam, "/")
   String destFileNameStr = StringFromList(parts - 1, urlStrParam, "/")
   if (strlen(destFileNameStr) < 1)
      Print "Error: Could not determine the name of the destination file."
```

```
      return 0
   endif

   Variable refNum
   Open/D/M="Save File As..."/T="????" refNum as destFileNameStr
   String fullFilePath = S_fileName

   if (strlen(fullFilePath) > 0) // No error and user didn't cancel in dialog.
      // Open the selected file so that it can later be written to.
      Open/Z/T="????" refNum as fullFilePath
      if (V_flag != 0)
         Print "There was an error opening the local destination file."
      else
         String response = FetchURL(url)
         Variable error = GetRTError(1)
         if (error == 0 && numtype(strlen(response)) == 0)
            FBinWrite refNum, response
            Close refNum
            Print "The file was successfully downloaded as " + fullFilePath
         else
            Close refNum
            DeleteFile/Z fullFilePath  // Clean up the empty file.
            Print "There was an error downloading the file."
         endif
      endif
   endif
End
```

Making a Query Via HTTP

Another use for HTTP requests is to get the server's response to a query. Many simple web forms use the HTTP GET method, which both FetchURL and URLRequest support. For example, you can simulate the submission of the basic Google search form using the following code.

```
Function WebQueryExample()
   String keywords
   String baseURL = "http://www.gutenberg.org/ebooks/search/"

   // Prompt the user to enter search keywords.
   Prompt keywords, "Enter search term"
   DoPrompt "Search Gutenberg.org", keywords
   if (V_flag == 1)
      return -1   // User clicked cancel button
   endif

   // Pass the search terms through URLEncode to
   // properly percent-encode them.
   keywords = URLEncode(keywords)

   // Build the full URL.
   String url = ""
   sprintf url, "%s?query=%s", baseURL, keywords

   // Fetch the results.
   String response
   response = FetchURL(url)
   Variable error = GetRTError(1)
   if (error != 0 || numtype(strlen(response)) != 0)
      Print "Error fetching search results."
      return -1
   endif
```

```
    // Try to extract the thumbnail image of the first result.
    String regExp = "(?s)<img class=\"cover-thumb\" src=\"(.+?)\".*"
    String firstURL
    SplitString/E=regExp response, firstURL
    firstURL = TrimString(firstURL)
    firstURL = "http:" + firstURL
    if (V_flag == 1)
       BrowseURL firstURL
    else
       Print "Could not extract the first result from the"
       Print "results page. Your search terms might not"
       Print "have given any results, or the format of"
       Print "the results may have changed so that the"
       Print "first result cannot be extracted."
       return -1
    endif

    return 0
End
```

Examples using the POST method can be found in the section ***The HTTP POST Method*** of the documentation for the **URLRequest** operation.

HTTP Troubleshooting

Here are some tips if you experience errors using **FetchURL** or **URLRequest**:

1. Use a web browser to connect to the site. This confirms that your network is operating, the server is operating, and that you are using the correct URL.
2. FetchURL and URLRequest generate an error if it cannot connect to the destination server, which could happen if your computer is not connected to the network or if the target URL contains an invalid host name or port number.

   However if the URL contains an invalid path or if the destination URL requires you to provide a username and password, these operations will likely not generate an error. The reason is these errors typically result in a web page being returned, though not the one you expected. If you need to check that a call to FetchURL returned a valid web page and not an error web page, you must do that in your own code. One possibility would be to try searching the page for key phrases, such as "File Not Found" or "Page Not Found".

   With URLRequest, you can inspect the value of the V_responseCode output variable. For successful HTTP requests, this value will usually be 200. A different value may indicate that there was an error making the request.

Operation Queue

Igor implements an operation queue that supports deferred execution of commands and some special commands for dealing with files, procedures, and experiments.

Igor services the operation queue when no procedures are running and the command line is empty. If the operation queue is not empty, Igor then executes the oldest command in the queue.

You can append a command to the operation queue using

```
Execute/P <command string>
```

The /P flag tells Igor to post the command to operation queue instead of executing it immediately.

You can also specify the /Q (quiet) or /Z (ignore error) flags. See **Execute/P** operation (page V-177) for details about /Q and /Z.

The command string can contain either a special command that is unique to the operation queue or ordinary Igor commands. The special commands are:

INSERTINCLUDE *procedureSpec*

DELETEINCLUDE *procedureSpec*

COMPILEPROCEDURES

NEWEXPERIMENT

LOADFILE *filePath*

MERGEEXPERIMENT *filePath*

Note: The special operation queue keywords must be all caps and must have exactly one space after the keyword.

INSERTINCLUDE and DELETEINCLUDE insert or delete #include lines in the main procedure window. *procedureSpec* is whatever you would use in a #include statement except for “#include” itself.

COMPILEPROCEDURES does just what it says, compiles procedures. You must call it after operations such as INSERTINCLUDE that modify, add, or remove procedure files.

NEWEXPERIMENT closes the current experiment without saving.

LOADFILE opens the file specified by *filePath*. *filePath* is either a full path or a path relative to the Igor Pro Folder. The file can be any file that Igor can open. If the file is an experiment file, execute NEWEXPERIMENT first to avoid displaying a “Do you want to save” dialog. If you want to save the changes in an experiment before loading another, you can use the standard SaveExperiment operation.

MERGEEXPERIMENT merges the experiment file specified by *filePath* into the current experiment. Before using this, make sure you understand the caveats regarding merging experiments. See **Merging Experiments** on page II-19 for details.

Here is an example:

```
Function DemoQueue()
   Execute/P "INSERTINCLUDE <Multi-peak fitting 1.3>"
   Execute/P "INSERTINCLUDE <Peak Functions>"
   Execute/P "COMPILEPROCEDURES "
   Execute/P "CreateFitSetupPanel()"
   Execute/P "Sleep 00:00:04"
   Execute/P "NEWEXPERIMENT "
   Execute/P "LOADFILE :Examples:Feature Demos:Live mode.pxp"
   Execute/P "DoWindow/F Graph0"
   Execute/P "StartButton(\"StartButton\")"
End
```

One important use of the operation queue is providing easy access to useful procedure packages. The "Igor Pro 7 Folder/Igor Procedures" folder contains a procedure file named “DemoLoader.ipf” that creates the Packages submenus found in various menus. To try it out, choose one of the items from the Analysis→Packages menu.

DemoLoader.ipf is an independent module. To examine it, execute:

```
SetIgorOption IndependentModuleDev=1
```

and then use the Windows→Procedure Windows submenu.

User-Defined Hook Functions

Igor calls specific user-defined functions, called “hook” functions, if they exist, when it performs certain actions. This allows savvy programmers to customize Igor’s behavior.

In some cases the hook function may inform Igor that the action has been completely handled, and that Igor shouldn't perform the action. For example, you could write a hook function to load data from a certain kind of text file that Igor can not handle directly.

This section discusses general hook functions that do not apply to a particular window. For information on window-specific events, see Window Hook Functions.

There are two ways to get Igor to call your general hook function. The first is by using a predefined function name. For example, if you create a function named AfterFileOpenHook, Igor will automatically call it after opening a file. The second way is to explicitly tell Igor that you want it to call your hook using the **SetIgorHook** operation.

If you use a predefined hook function name, you should make the function static (private to the file containing it) so that other procedure files can use the same predefined name.

Here are the predefined hook functions.

Action	Hook Function Called
Procedures were successfully compiled	**AfterCompiledHook**
A file or experiment was opened	**AfterFileOpenHook**
The Windows-only "MDI frame" (main application window) was resized	**AfterMDIFrameSizedHook**
A target window was created	**AfterWindowCreatedHook**
The debugger window is about to open	**BeforeDebuggerOpensHook**
An experiment is about to be saved	**BeforeExperimentSaveHook**
A file or XOP is about to be opened	**BeforeFileOpenHook**
Igor is about to open a new experiment	**IgorBeforeNewHook**
Igor is about to quit	**IgorBeforeQuitHook**
Igor is building and enabling menus or about to handle a menu selection	**IgorMenuHook**
Igor is about to quit	**IgorQuitHook**
Igor launching or creating a new experiment	**IgorStartOrNewHook**

To create hook functions, you must write functions with the specified names and store them in any procedure file. If you store the procedure file in "Igor Pro User Files/Igor Procedures" (see **Igor Pro User Files** on page II-31 for details), Igor will automatically open the file and compile the functions when it starts up and will execute the IgorStartOrNewHook function if it exists.

To allow for multiple procedure files to define the same predefined hook function, you should declare your hook function static. For example:

```
static Function IgorStartOrNewHook(igorApplicationNameStr)
   String igorApplicationNameStr
```

The use of the static keyword makes the function private to the procedure file containing it and allows other procedure files to have their own static function with the same name.

Igor calls static hook functions after the **SetIgorHook** functions are called. The static hook functions themselves are called in the order in which their procedure file was opened. You should not rely on any execution order among the static hook functions. However, any hook function which returns a nonzero result prevents remaining hook functions from being called and prevents Igor from performing its usual processing of the hook event. In most cases hook functions should exercise caution in returning any value other than 0. For hook functions only, returning a NaN or failing to return a value (which returns a NaN) is considered the same as returning 0.

The following sections describe the individual hook functions in detail.

AfterCompiledHook

`AfterCompiledHook()`

AfterCompiledHook is a user-defined function that Igor calls after the procedure windows have all been compiled successfully.

You can use AfterCompiledHook to initialize global variables or data folders, among other things.

The function result from AfterCompiledHook must be 0. All other values are reserved for future use.

See Also

SetIgorHook, **User-Defined Hook Functions** on page IV-264.

AfterFileOpenHook

`AfterFileOpenHook(`*`refNum`*`, `*`fileNameStr`*`, `*`pathNameStr`*`, `*`fileTypeStr`*`,`
***`fileCreatorStr`*`, `*`fileKind`*`)`**

AfterFileOpenHook is a user-defined function that Igor calls after it has opened a file because the user dragged it onto the Igor icon or into Igor or double-clicked it.

AfterFileOpenHook is not called when a file is opened via a menu.

Windows system files with .bin, .com, .dll, .exe, and .sys extensions aren't passed to the hook functions.

The parameters contain information about the file, which has already been opened for read-only access.

AfterFileOpenHook's return value is ignored unless *fileKind* is 9. If the returned value is zero, the default action is performed.

Parameters

refNum is the file reference number. You use this number with file I/O operations to read from the file. Igor closes the file when the user-defined function returns, and *refNum* becomes invalid. The file is opened for read-only; if you want to write to it, you must close and reopen it with write access. *refNum* will be -1 for experiment files and XOPs. In this case, Igor has not opened the file for you.

fileNameStr contains the name of the file.

pathNameStr contains the name of the symbolic path. *pathNameStr* is not the value of the path. Use the **PathInfo** operation to determine the path's value.

fileTypeStr contains the Macintosh file type, if applicable. File type codes are obsolete. Use the file name extension to determine if you want to handle the file. You can use **ParseFilePath** to obtain the extension from *fileNameStr*.

fileCreatorStr contains the Macintosh creator code, if applicable. Creator codes are obsolete so ignore this parameter.

fileKind is a number that identifies what kind of file Igor thinks it is. Values for *fileKind* are listed in the next section.

AfterFileOpenHook *fileKind* Parameter

This table describes the AfterFileOpenHook function *fileKind* parameter.

If the user's AfterFileOpenHook function returns 0, Igor performs the default action listed in the table:

Kind of File	*fileKind*	Default Action, if Any
Unknown	0	
Igor Experiment, packed (stationery, too)	1	
Igor Experiment, unpacked (stationery, too)	2	
Igor XOP	3	
Igor Binary File	4	
Igor Text (data and commands)	5	
Text, no numbers detected in first two lines	6	
General Numeric text (no tabs)	7	
Numeric text Tab-Separated-Values	8	
Numeric text Tab-Separated-Values, MIME	9	Display loaded data in a new table and a new graph.
Text, with tabs	10	
Igor Notebook (unformatted or formatted)	11	
Igor Procedure	12	
Igor Help	13	

Details

AfterFileOpenHook's return value is ignored, except when *fileKind* is 9 (Numeric text, Tab-Separated-Values, MIME). If you return a value of 0, Igor executes the default action, which displays the loaded data in a table and a graph. If you return a value of 1, Igor does nothing.

Another way to disable the MIME-TSV default action is define a global variable named V_no_MIME_TSV_Load (in the root data folder) and set its value to 1. In this case any file of *fileKind* = 9 is reassigned a *fileKind* of 8.

The default action for *fileKind* = 9 makes Igor a MIME-TSV document Helper Application for Web browsers such as Netscape or Internet Explorer.

The exact criteria for Igor to consider a file to be of kind 9 are:

- *fileTypeStr* must be "TEXT" or "WMT0" (that's a zero, not an oh).
- Either the first line of the file must begin with a # character, or the name of the file must end with ".tsv" in either lower or upper case.
- The first line must contain one or more column titles. If the line starts with a # character, the first column title must not start with "include", "pragma" or the ! character. Spaces are allowed in the titles, but if two or more title columns are present, they must be separated by one tab character.
- The second line must contain one or more numbers. If two or more numbers, they must be separated by one tab character, and the first line's words must also be separated by tabs.

When the MIME-TSV file contains one column of data, it is graphed as a series of Y values.

Short columns (less than 50 values) are graphed with lines and markers, longer columns with lines only. Preferences are turned on when the graph is made.

Two columns are assumed to be X followed by Y, and are graphed as Y versus X. More columns do not affect the graph, though they are shown in the table.

Example

```
// This hook function prints the first line of opened TEXT files
// into the history area
Function AfterFileOpenHook(refNum,file,pathName,type,creator,kind)
   Variable refNum,kind
   String file,pathName,type,creator
   // Check that the file is open (read only), and of correct type
   if( (refNum >= 0) && (CmpStr(type,"TEXT")==0) )  // also "text", etc.
      String line1
      FReadLine refNum, line1 // Read the line (and carriage return)
      Print line1       // Print line in the history area.
   endif
   return 0             // don't prevent MIME-TSV from displaying
End
```

See Also

BeforeFileOpenHook and **SetIgorHook**.

BeforeDebuggerOpensHook

BeforeDebuggerOpensHook(*errorInRoutineStr*, *stoppedByBreakpoint*)

BeforeDebuggerOpensHook is a user-defined function that Igor calls when the debugger window is about to be opened, whether by hitting a breakpoint or when Debug on Error is enabled.

BeforeDebuggerOpensHook can be used to prevent the debugger window opening for certain error codes or in selected user-defined functions when Debug on Error is enabled. This is a feature for advanced programmers only. Most programmers will not need it.

This hook does not work well for macros or procs, because their runtime errors don't automatically open the debugger, but instead present an error dialog from which the user manually enters the debugger by clicking the Debug button.

Parameters

errorInRoutineStr contains the name of the routine (function or macro) the debugger will be stopping in as a fully-qualified name, comprised of at least "`ModuleName#RoutineName`", suitable for use with FunctionInfo.

If the routine is in a regular module procedure window (see **Regular Modules** on page IV-222), *errorInRoutineStr* will be a triple name such as "`MyIM#MyModule#MyFunction`".

stoppedByBreakpoint is 0 if the debugger is about to be shown because of Debug on Error, or non-zero if the debugger encountered a user-set breakpoint (see **Setting Breakpoints** on page IV-199).

If a breakpoint exists at the line where an error caused the debugger to appear, *stoppedByBreakpoint* will be non-zero, even though the cause was Debug on Error.

Details

If BeforeDebuggerOpensHook returns 0 or NaN (or doesn't return a value), the debugger window is opened normally.

If it returns 1, the debugger window is not shown and program execution continues.

All other return values are reserved for future use.

Example

The following hypothetical example:

1. Prevents breakpoints from bringing up the debugger, unless DEBUGGING is defined.
2. Prints the name of the routine with the error, and the error message.
3. Beeps before the debugger appears.

```
Function ProvokeDebuggerInFunction()
   DebuggerOptions enable=1, debugOnError=1     // Enable debug on error

   ProvokeDebugger()
```

```
End

Function ProvokeDebugger()
   Variable var=0 // Put a breakpoint here.
                  // Without a #define DEBUGGING, the breakpoint is skipped.
   Make/O $""     // Cause an error
   Print "Back from bad Make command in function"
End

static Function BeforeDebuggerOpensHook(pathToErrorFunction,isUserBreakpoint)
   String pathToErrorFunction
   Variable isUserBreakpoint

   #ifndef DEBUGGING
      if( isUserBreakpoint )
         return 1 // Ignore user breakpoints we forgot to clear.
                  // Don't use this during development!
      endif
   #endif

   Print "stackCrawl = ", GetRTStackInfo(0)
   Print "FunctionInfo = ", FunctionInfo(pathToErrorFunction)

   // Don't clear errors unless you're preventing the debugger from appearing
   Variable clearErrors= 0
   Variable rtErr= GetRTError(clearErrors)   // Get the error #

   Variable substitutionOption= exists(pathToErrorFunction)== 3 ? 3 : 2
   String errorMessage= GetErrMessage(rtErr,substitutionOption)

   Beep     // Audible cue that the debugger is showing up!

   Print "Error \""+errorMessage+"\" in "+pathToErrorFunction+"

   return 0 // Return 0 to show the debugger; an unexpected error occurred.
End

•ProvokeDebuggerInFunction()  // Execute this in the command line
  stackCrawl =
      ProvokeDebuggerInFunction;ProvokeDebugger;BeforeDebuggerOpensHook;
  FunctionInfo =
      NAME:ProvokeDebugger;PROCWIN:Procedure;MODULE:;INDEPENDENTMODULE:;...
  Error "Expected name" in ProcGlobal#ProvokeDebugger
  Back from bad Make command in function
```

See Also

SetWindow, **SetIgorHook**, and **User-Defined Hook Functions** on page IV-264

Static Functions on page IV-96, **Regular Modules** on page IV-222, **Independent Modules** on page IV-224

FunctionInfo, **GetRTStackInfo**, **GetRTError**, **GetRTErrMessage**

Conditional Compilation on page IV-100

AfterMDIFrameSizedHook

`AfterMDIFrameSizedHook(`*`param`*`)`

AfterMDIFrameSizedHook is a user-defined function that Igor calls when the Windows-only "MDI frame" (main application window) has been resized.

AfterMDIFrameSizedHook can be used to resize windows to fit the new frame size. See **GetWindow** kwFrame and **MoveWindow**.

Parameters

param is one of the following values:

Size Event	*param*
Normal resize	`0`
Minimized	`1`
Maximized	`2`
Moved	`3`

Details

This function is not called on Macintosh.

Resizing the MDI frame by the top left corner calls AfterMDIFrameSizedHook twice: first for the move (param = 3) and then for the normal resize (param = 0).

Igor currently ignores the value returned by AfterMDIFrameSizedHook. Return 0 in case Igor uses this value in the future.

See Also

SetWindow, **GetWindow**, **SetIgorHook**, and **User-Defined Hook Functions** on page IV-264.

AfterWindowCreatedHook

`AfterWindowCreatedHook(`*`windowNameStr, winType`*`)`

AfterWindowCreatedHook is a user-defined function that Igor calls when a target window is first created.

AfterWindowCreatedHook can be used to set a window hook on target windows created by the user or by other procedures.

Parameters

windowNameStr contains the name of the created window.

winType is the type of the window, the same value as returned by **WinType**.

Details

"Target windows" are graphs, tables, layout, panels, and notebook windows.

AfterWindowCreatedHook is not called when an Igor experiment is being opened.

Igor ignores the value returned by AfterWindowCreatedHook.

See Also

SetWindow, **SetIgorHook**, and **User-Defined Hook Functions** on page IV-264.

BeforeExperimentSaveHook

`BeforeExperimentSaveHook(`*`refNum, fileNameStr, pathNameStr, fileTypeStr, fileCreatorStr, fileKind`*`)`

BeforeExperimentSaveHook is a user-defined function that Igor calls when an experiment is about to be saved by Igor.

Igor ignores the value returned by BeforeExperimentSaveHook.

Parameters

refNum is -1. Ignore this parameter.

fileNameStr contains the name of the file.

pathNameStr contains the name of the symbolic path. *pathNameStr* is not the value of the path. Use the **PathInfo** operation to determine the path's value.

fileTypeStr contains the Macintosh file type, if applicable. File type codes are obsolete. Use the file name extension to determine if you want to handle the file. You can use **ParseFilePath** to obtain the extension from *fileNameStr*

fileCreatorStr contains the Macintosh creator code, if applicable. Creator codes are obsolete so ignore this parameter.

Variable *fileKind* is a number that identifies what kind of file Igor will be saving:

Kind of File	*fileKind*
Igor Experiment, packed*	1
Igor Experiment, unpacked*	2

* Including stationery experiment files.

Details

You can determine the full directory and file path of the experiment by calling the **PathInfo** operation with $*pathNameStr*.

Example

This example prints the full file path of the about-to-be-saved experiment to the history area, and deletes all unused symbolic paths.

```
#pragma rtGlobals=1        // treat S_path as local string variable

Function BeforeExperimentSaveHook(rN,fileName,path,type,creator,kind)
   Variable rN,kind
   String fileName,path,type,creator

   PathInfo $path            // puts path value into (local) S_path
   Printf "Saved \"%s\" experiment\r",S_path+fileName

   KillPath/A/Z              // Delete all unneeded symbolic paths
End
```

See Also

The **SetIgorHook** operation.

BeforeFileOpenHook

BeforeFileOpenHook(*refNum*, *fileNameStr*, *pathNameStr*, *fileTypeStr*, *fileCreatorStr*, *fileKind*)

BeforeFileOpenHook is a user-defined function that Igor calls when a file *is* about to be opened because the user dragged it onto the Igor icon or into Igor or double-clicked it.

BeforeFileOpenHook is not called when a file is opened via a menu.

Windows system files with .bin, .com, .dll, .exe, and .sys extensions aren't passed to the hook functions.

The value returned by BeforeFileOpenHook informs Igor whether the hook function handled the open event and therefore Igor should not perform its default action. In some cases, this return value is ignored, and Igor performs the default action anyway.

Parameters

refNum is the file reference number. You use this number with file I/O operations to read from the file. Igor closes the file when the user-defined function returns, and *refNum* becomes invalid. The file is opened for read-only; if you want to write to it, you must close and reopen it with write access. *refNum* will be -1 for experiment files and XOPs. In this case, Igor has not opened the file for you.

fileNameStr contains the name of the file.

pathNameStr contains the name of the symbolic path. *pathNameStr* is not the value of the path. Use the **PathInfo** operation to determine the path's value.

fileTypeStr contains the Macintosh file type, if applicable. File type codes are obsolete. Use the file name extension to determine if you want to handle the file. You can use **ParseFilePath** to obtain the extension from *fileNameStr*

fileCreatorStr contains the Macintosh creator code, if applicable. Creator codes are obsolete so ignore this parameter.

fileKind is a number that identifies what kind of file Igor thinks it is. Values for *fileKind* are listed in the next section.

BeforeFileOpenHook *fileKind* Parameter

This table describes the BeforeFileOpenHook function *fileKind* parameter.

Kind of File	*fileKind*	Default Action, if Any
Unknown	0	
Igor Experiment, packed *	1	(Hook not called)
Igor Experiment, unpacked*	2	(Hook not called)
Igor XOP	3	
Igor Binary file	4	Data loaded
Igor Text (data and commands)	5	Data loaded, commands executed
Text, no numbers detected in first two lines	6	Opened as unformatted notebook
General Numeric text (no tabs)	7	Data loaded as general text
Numeric text Tab-Separated-Values	8	Data loaded as delimited text
Numeric text Tab-Separated-Values, MIME	9	Display loaded data in a new table and a new graph.
Text, with tabs	10	Opened as unformatted notebook
Igor Notebook (unformatted or formatted)	11	Opened as notebook
Igor Procedure	12	*Always* opened as procedure file
Igor Help	13	*Always* opened as help file

* Including stationery experiment files.

Details

BeforeFileOpenHook must return 1 if Igor is not to take action on the file (it won't be opened), or 0 if Igor is permitted to take action on the file. Igor ignores the return value for *fileKind* values of 3, 12, and 13. The hook function is not called for Igor experiments (*fileKind* values of 1 and 2).

Igor always closes the file when the user-defined function returns, and *refNum* becomes invalid (don't store the value of *refNum* in a global for use by other routines, since the file it refers to has been closed).

Example

This example checks the first line of the file about to be opened to determine whether it has a special, presumably user-specific, format. If it does, then LoadMyFile (another user-defined function) is called to load it. LoadMyFile presumably loads this custom data file, and returns 1 if it succeeded. If it returns 0 then Igor will open it using the Default Action from the above table.

```
Function BeforeFileOpenHook(refNum,fileName,path,type,creator,kind)
   Variable refNum,kind
   String fileName,path,type,creator

   Variable handledOpen=0
   if( CmpStr(type,"TEXT")==0 )              // text files only
      String line1
      FReadLine refNum, line1 // First line (and carriage return)
      if( CmpStr(line1[0,4],"XYZZY") == 0 )  // My special file
         FSetPos refNum, 0             // rewind to start of file
         handledOpen= LoadMyFile(refNum)  // returns 1 if loaded OK
      endif
   endif
   return handledOpen   // 1 tells Igor not to open the file
End
```

See Also
AfterFileOpenHook and **SetIgorHook**.

IgorBeforeNewHook

`IgorBeforeNewHook(`*`igorApplicationNameStr`*`)`

IgorBeforeNewHook is a user-defined function that Igor calls before a new experiment is opened in response to the New Experiment, Revert Experiment, or Open Experiment menu items in the File menu.

You can use IgorBeforeNewHook to clean up the current experiment, or to avoid losing unsaved data even if the user chooses to not save the current experiment.

Igor ignores the value returned by IgorBeforeNewHook.

Parameters
igorApplicationNameStr contains the name of the currently running Igor Pro application.

See Also
IgorStartOrNewHook and **SetIgorHook**.

IgorBeforeQuitHook

`IgorBeforeQuitHook(`*`unsavedExp,unsavedNotebooks,unsavedProcedures`*`)`

IgorBeforeQuitHook is a user-defined function that Igor calls just before Igor is about to quit, before any save-related dialogs have been presented.

Parameters
unsavedExp is 0 if the experiment is saved, non-zero if unsaved.

unsavedNotebooks is the count of unsaved notebooks.

unsavedProcedures is the count of unsaved procedures.

The save state of packed procedure and notebook files is part of *unsavedExp*, not *unsavedNotebooks* or *unsavedProcedures*. This applies to adopted procedure and notebook files and new procedure and notebook windows that have never been saved.

Details
IgorBeforeQuitHook should normally return 0. In this case, Igor presents the “Do you want to save” dialog, and if the user approves, proceeds with the quit, which includes calling IgorQuitHook.

If IgorBeforeQuitHook returns 1, then the quit is aborted. The current experiment, notebooks, and procedures are not saved, no dialogs are presented to the user, and IgorQuitHook is not called.

See Also
IgorQuitHook and **SetIgorHook**.

IgorMenuHook

`IgorMenuHook(`*`isSelection, menuStr, itemStr, itemNo, activeWindowStr, wType`*`)`

IgorMenuHook is a user-defined function that Igor calls just before and just after menu selection, whether by mouse or keyboard.

Parameters
isSelection is 0 before a menu item has been selected and 1 after a menu item has been selected.

When *isSelection* is 1, *menuStr* is the name of the selected menu. It is always in English, regardless of the localization of Igor. When *isSelection* is 0, *menuStr* is "".

When *isSelection* is 1, *itemStr* is the name of the selected menu item. When *isSelection* is 0, *itemStr* is "".

When *isSelection* is 1, *itemNo* is the one-based item number of the selected menu item. When *isSelection* is 0, *itemNo* is 0.

activeWindowStr identifies the active window. See details below.

wType identifies the kind of window that *activeWindowStr* identifies. It returns the same values as the **WinType** function.

activeWindowStr Parameter

activeWindowStr identifies the window to which the menu selection will apply. It can be a window name, window title, or special keyword, as follows:

Window	*activeWindowStr*
Target window	Window name. The target window is that top graph, table, page layout, notebook, control panel, Gizmo plot, or XOP target window.
Command window	`kwCmdHist` (as used with **GetWindow**).
Procedure window	Window title as shown in the window's title bar. The built-in procedure window is "Procedure".
XOP non-target window	The window title as shown in the window's title bar.

See **Window Names and Titles** on page II-40 for a discussion of the distinction.

Details

IgorMenuHook is called with *isSelection* set to 0 after all the menus have been enabled and before a mouse click or keyboard equivalent is handled.

The return value should normally be 0. If the return value is nonzero (1 is usual) then the active window's hook function (see **SetWindow** operation on page V-739) is not called for the enablemenu event.

IgorMenuHook is called with *isSelection* set to 1 after the menu has been selected and before Igor has acted on the selection.

If the IgorMenuHook function returns 0, Igor proceeds to call the active window's hook function for the menu event. (If the window hook function exists and returns nonzero, Igor ignores the menu selection. Otherwise Igor handles the menu selection normally.)

If the IgorMenuHook function returns nonzero (1 is recommended), Igor does not call the remaining hook functions and Igor ignores the menu selection.

Example

This example invokes the Export Graphics menu item when Command-C (*Macintosh*) or Ctrl+C (*Windows*) is selected for all graphs, preventing Igor from performing the usual Copy.

```
Function IgorMenuHook(isSel, menuStr, itemStr, itemNo, activeWindowStr, wt)
   Variable isSel
   String menuStr, itemStr
   Variable itemNo
   String activeWindowStr
   Variable wt

   Variable handled= 0
   if( Cmpstr(menuStr,"Edit") == 0 && CmpStr(itemStr,"Copy") == 0 )
      if( wt == 1 )                                  // graph
         // DoIgorMenu would cause recursion, so we defer execution
         Execute/P/Q/Z "DoIgorMenu \"Edit\", \"Export Graphics\""
         handled= 1
      endif
   endif

   return handled
End
```

See Also

SetWindow, **Execute**, and **SetIgorHook**.

IgorQuitHook

`IgorQuitHook(`*`igorApplicationNameStr`*`)`

IgorQuitHook is a user-defined function that Igor calls when Igor is about to quit.

The value returned by IgorQuitHook is ignored.

Parameters

igorApplicationNameStr contains the name of the currently running Igor Pro application (including the .exe extension under Windows).

Details

You can determine the full directory and file path of the Igor application by calling the **PathInfo** operation with the Igor path name. See the example in **IgorStartOrNewHook** on page IV-275.

See Also

IgorBeforeQuitHook and **SetIgorHook**.

IgorStartOrNewHook

`IgorStartOrNewHook(igorApplicationNameStr)`

IgorStartOrNewHook is a user-defined function that Igor calls when starting up and when creating a new experiment. It is also called if Igor is launched as a result of double-clicking a saved Igor experiment.

Igor ignores the value returned by IgorStartOrNewHook.

Parameters

igorApplicationNameStr contains the name of the currently running Igor Pro application (including the .exe extension under Windows).

Details

You can determine the full directory and file path of the Igor application by calling the **PathInfo** operation with the Igor path name.

Example

This example prints the full path of Igor application whenever Igor starts up or creates a new experiment:

```
Function IgorStartOrNewHook(igorApplicationNameStr)
	String igorApplicationNameStr

	PathInfo Igor			// puts path value into (local) S_path
	printf "\"%s\" (re)starting\r", S_path + igorApplicationNameStr
End
```

See Also

IgorBeforeNewHook and **SetIgorHook**.

Window User Data

The window user data feature provides a way for packages that create or manage windows to store per-window settings. You can store arbitrary data with a window using the userdata keyword with the **SetWindow**.

Each window has a primary, unnamed user data that is used by default.

You can also store an unlimited number of different user data strings by specifying a name for each different user data string. The name can be any legal Igor name. It should be distinct to prevent clashes between packages.

Packages should use named user data.

You can retrieve information from the default user data using the **GetWindow**. To retrieve named user data, you must use the **GetUserData**.

Here is a simple example of user data using the top window:

```
SetWindow kwTopWin,userdata= "window data"
Print GetUserData("","","")
```

Although there is no size limit to how much user data you can store, it does have to be stored as part of the recreation macro for the window when experiments are saved. Consequently, huge user data can slow down experiment saving and loading

Window Hook Functions

A window hook function is a user-defined function that receives notifications of events that occur in a specific window. Your window hook function can detect and respond to events of interest. You can then allow Igor to also process the event or inform Igor that you have handled it.

This section discusses window hook functions that apply to a specific window. For information on general events hooks, see **User-Defined Hook Functions** on page IV-264.

To handle window events, you first write a window hook function and then use the **SetWindow** operation to install the hook on a particular window. This example shows how you would detect arrow key events in a particular window. To try it, paste the code below into the procedure window and then execute `DemoWindowHook()`:

```
Function MyWindowHook(s)
   STRUCT WMWinHookStruct &s

   Variable hookResult = 0 // 0 if we do not handle event, 1 if we handle it.

   switch(s.eventCode)
      case 11:             // Keyboard event
         switch (s.keycode)
            case 28:
               Print "Left arrow key pressed."
               hookResult = 1
               break
            case 29:
               Print "Right arrow key pressed."
               hookResult = 1
               break
            case 30:
               Print "Up arrow key pressed."
               hookResult = 1
               break
            case 31:
               Print "Down arrow key pressed."
               hookResult = 1
               break
            default:
               // The keyText field requires Igor Pro 7 or later
               // See Keyboard Events on page IV-281
               Printf "Key pressed: %s\r", s.keyText
               break
         endswitch
         break
   endswitch

   return hookResult // If non-zero, we handled event and Igor will ignore it.
End

Function DemoWindowHook()
   DoWindow/F DemoGraph    // Does graph exist?
   if (V_flag == 0)
      Display /N=DemoGraph // Create graph
      SetWindow DemoGraph, hook(MyHook)=MyWindowHook  // Install window hook
   endif
End
```

The window hook function receives a WMWinHookStruct structure as a parameter. WMWinHookStruct is a built-in structure that contains all of the information you might need to respond to an event. One of its fields, the eventCode field, specifies what kind of event occurred.

If your hook function returns 1, this tells Igor that you handled the event and Igor does not handle it. If your hook function returns 0, this tells Igor that you did not handle the event, so Igor does handle it.

This example uses a named window hook. In this case the name is MyHook. More than one procedure file can install a hook on a given window. The purpose of the name is to allow a package to install and remove its own hook function without disturbing the hook functions of other packages. Choose a distinct hook function name that is unlikely to conflict with other hook names.

Earlier versions of Igor supported only one unnamed hook function. This meant that only one package could hook any particular window. Unnamed hook functions are still supported for backward compatibility but new code should always use named hook functions.

Window Hooks and Subwindows

Igor calls window hook functions for top-level windows only, not for subwindows. If you want to hook a subwindow, you must set the hook on the top-level window. In the hook function, test to see if the subwindow is active. For example, this code, at the start of a window hook function, insures that the hook runs only if a subwindow named G0 is active.

```
GetWindow $s.winName activeSW
String activeSubwindow = S_value
if (CmpStr(activeSubwindow,"G0") != 0)
   return 0
endif
```

Exterior panels (see **Exterior Control Panels** on page III-394) are top-level windows even though they are subwindows. To hook an exterior subwindow, you must install the hook on the exterior panel using subwindow syntax.

Named Window Hook Functions

A named window hook function takes one parameter - a `WMWinHookStruct` structure. This built-in structure provides your function with information about the status of various window events.

The named window hook function has this format:

```
Function MyWindowHook(s)
   STRUCT WMWinHookStruct &s

   Variable hookResult = 0

   switch(s.eventCode)
      case 0:              // Activate
         // Handle activate
         break

      case 1:              // Deactivate
         // Handle deactivate
         break

      // And so on . . .
   endswitch

   return hookResult       // 0 if nothing done, else 1
End
```

If you handle a particular event and you want Igor to ignore it, return 1 from the hook function. However, you cannot make Igor ignore a window kill event - once the kill event is received the window will be killed.

Named Window Hook Events

Here are the events passed to a named window hook function:

eventCode	`eventName`	Notes
0	"Activate"	
1	"Deactivate"	
2	"Kill"	Returning 1 when you receive this event does not cause Igor to ignore the event. At this point, you cannot prevent the window from being killed. See the killVote event to prevent the window being killed.
3	"Mousedown"	
4	"Mousemoved"	
5	"Mouseup"	
6	"Resize"	
7	"Cursormoved"	See **Cursors — Moving Cursor Calls Function** on page IV-316.
8	"Modified"	A modification to the window has been made. This is sent to graph and notebook windows only. It is an error to try to kill a notebook window from the window hook during the modified event.
9	"Enablemenu"	
10	"Menu"	
11	"Keyboard"	
12	"moved"	
13	"renamed"	
14	"subwindowKill"	One of the window's subwindows is about to be killed.
15	"hide"	The window or one of its subwindows is about to be hidden. See **Window Hook Show and Hide Events** on page IV-284.
16	"show"	The window or one of its subwindows is about to be unhidden. See **Window Hook Show and Hide Events** on page IV-284.
17	"killVote"	Window is about to be killed. Return 2 to prevent the window from being killed, otherwise return 0. **Note**: Don't delete data structures during this event, use killVote only to decide whether the window kill should actually happen. Delete data structures in the kill event. See **Window Hook Deactivate and Kill Events** on page IV-283.
18	"showTools"	
19	"hideTools"	
20	"showInfo"	
21	"hideInfo"	
22	"mouseWheel"	
23	"spinUpdate"	This event is sent only to windows marked via DoUpdate/E=1 as progress windows. It is sent when Igor spins the beachball cursor. See **Progress Windows** on page IV-144 for details.

WMWinHookStruct

The `WMWinHookStruct` structure has members as described in the following tables:

Base `WMWinHookStruct` Structure Members

Member	Description
`char winName[MAX_PATH_LENGTH+1]`	hcSpec of the affected (sub)window.
`STRUCT Rect winRect`	Local coordinates of the affected (sub)window.
`STRUCT Point mouseLoc`	Mouse location.
`double ticks`	Tick count when event happened.
`Int32 eventCode`	See see **eventCode** table on page IV-278.
`char eventName[31+1]`	Name-equivalent of `eventCode`, see **eventCode** table on page IV-278. Added in Igor 5.03.
`Int32 eventMod`	Bitfield of modifiers. See description for `MODIFIERS:`*`flags`*.

Members of `WMWinHookStruct` Structure Used with `menu` Code

Member	Description
`char menuName[255+1]`	Name of menu (in English) as used by **SetIgorMenuMode**.
`char menuItem[255+1]`	Text of the menu item as used by SetIgorMenuMode

Members of `WMWinHookStruct` Structure Used with `keyboard` Code

Member	Description
`Int32 keycode`	ASCII value of key struck. Function keys are not available but navigation keys are translated to specific values and will be the same on Macintosh and Windows. This field can not represent non-ASCII text such as accented characters. Use keyText instead.
`Int32 specialKeyCode`	See **Keyboard Events** on page IV-281. This field was added in Igor Pro 7.
`char keyText[16]`	UTF-8 representation of key struck. This field was added in Igor Pro 7.

Members of `WMWinHookStruct` Structure Used with `cursormoved` Code

Member	Description
`char traceName[MAX_OBJ_NAME+1]`	The name of the trace or image to which the moved cursor is attached or which supplies the X (and Y) values. Can be `""` if the cursor is free.
`char cursorName[2]`	Cursor name A through J.
`double pointNumber`	Point number of the trace or the X (row) point number of the image where the cursor is attached.

Members of `WMWinHookStruct` Structure Used with `cursormoved` Code

Member	Description
	If the cursor is "free", `pointNumber` is actually the fractional relative *xValue* as used in the **Cursor**/F/P command.
double yPointNumber	Valid only when the cursor is attached to a two-dimensional item such as an image, contour, or waterfall plot, or when the cursor is free.
	If attached to an image, contour, or waterfall plot, `yPointNumber` is the Y (column) point number of the image where the cursor is attached.
	If the cursor is "free", `yPointNumber` is actually the fractional relative *yValue* as used in the **Cursor**/F/P command.
Int32 isFree	Has value of 1 if the cursor is not attached to anything, or value of 0 if it is attached to a trace, image, contour, or waterfall.

Members of `WMWinHookStruct` Structure Used with `mouseWheel` Code

Member	Description
double wheelDy	Vertical lines to scroll. Typically +1 or -1.
double wheelDx	Horizontal lines to scroll. Typically +1 or -1.
	On Windows, horizontal mouse wheel requires Vista.

Members of `WMWinHookStruct` Used with `renamed` Code

Member	Description
char oldWinName[MAX_OBJ_NAME+1]	Old name of the window or subwindow. Not the absolute path *hcSpec*, just the name.

User-Modifiable Members of `WMWinHookStruct` Structure

Member	Description
Int32 doSetCursor	Set to 1 to change cursor to that specified by `cursorCode`.
Int32 cursorCode	See **Setting the Mouse Cursor**.

Mouse Events

Igor sends mouse down and mouse up events with the `eventCode` field of the `WMWinHookStruct` structure set to 3 or 5. With rare exceptions, your hook function should act on the mouse up event.

In Igor7, a mouse click on a table cell causes Igor to send a mouse down event to your hook function before Igor acts on the click, allowing you to block the action by returning a non-zero result. Igor then sends a mouse down event after Igor has acted on the click.

In Igor6, the mouse down event was sent only when the selection was finished, that is, after the mouse up event occurred. If you have existing code that uses the mouse down event to get a table selection, you need to change your code to use the mouse up event.

Keyboard Events

The `WMWinHookStruct` structure has three members used with keyboard events.

The `keycode` field works with ASCII characters and some special keys such as keyboard navigation keys.

The `specialKeyCode` fields works with navigation keys, function keys and other special keys. `specialKeyCode` is zero for normal text such as letters, numbers and punctuation.

The `keyText` field works with ASCII characters and non-ASCII characters such as accented characters.

The `specialKeyCode` and `keyText` fields were added in Igor Pro 7. New code that does not need to run with earlier Igor versions should use these new fields instead of the keycode field. See **Keyboard Events Example** on page IV-281 for an example.

Here are the codes for the `specialKeyCode` and `keyCode` fields:

Key	specialKeyCode	keyCode	Note
F1 through F39	1 through 39	Not supported	Function keys
LeftArrow	100	28	
RightArrow	101	29	
UpArrow	102	30	
DownArrow	103	31	
PageUp	104	11	
PageDown	105	12	
Home	106	1	
End	107	4	
Return	200	13	
Enter	201	3	
Tab	202	27	
BackTab	203	Not supported	Tab with Shift pressed
Escape	204	27	
Delete	300	8	Backspace key
ForwardDelete	301	127	
Clear	302	Not supported	
Insert	303	Not supported	
Help	400	Not supported	
Break	401	Not supported	Pause/Break key
Print	402	Not supported	
SysReq	403	Not supported	

Keyboard Events Example

This example illustrates the use of the various keyboard event fields in the WMWinHookStruct structure. It requires Igor Pro 7 or later.

```
Function KeyboardWindowHook(s)
   STRUCT WMWinHookStruct &s
```

```
	Variable hookResult = 0	// 0 if we do not handle event, 1 if we handle it.

	String message = ""

	switch(s.eventCode)
		case 11:			// Keyboard event
			String keyCodeInfo
			sprintf keyCodeInfo, "s.keycode = 0x%04X", s.keycode
			if (strlen(message) > 0)
				message += "\r"
			endif
			message +=keyCodeInfo

			message += "\r"
			String specialKeyCodeInfo
			sprintf specialKeyCodeInfo, "s.specialKeyCode = %d", s.specialKeyCode
			message +=specialKeyCodeInfo
			message += "\r"

			String keyTextInfo
			sprintf keyTextInfo, "s.keyText = \"%s\"", s.keyText
			message +=keyTextInfo

			String text = "\\Z24" + message
			Textbox /C/N=Message/W=KeyboardEventsGraph/A=MT/X=0/Y=15 text

			hookResult = 1	// We handled keystroke
			break
	endswitch

	return hookResult // If non-zero, we handled event and Igor will ignore it.
End

Function DemoKeyboardWindowHook()
	DoWindow/F KeyboardEventsGraph		// Does graph exist?
	if (V_flag == 0)
		// Create graph
		Display /N=KeyboardEventsGraph as "Keyboard Events"

		// Install hook
		SetWindow KeyboardEventsGraph, hook(MyHook)=KeyboardWindowHook

		String text = "\\Z24" + "Press a key"
		Textbox /C/N=Message/W=KeyboardEventsGraph/A=MT/X=0/Y=15 text
	endif
End
```

Setting the Mouse Cursor

An advanced programmer can use a named window hook function to change the mouse cursor.

You might want to do this, for example, if your window hook function intercepts mouse events on certain items (e.g., waves) and performs custom actions. By setting a custom mouse cursor you indicate to the user that clicking the items results in different-from-normal actions.

See the Mouse Cursor Control example experiment - in Igor choose File→Example Experiments→Programming→Mouse Cursor Control.

Panel Done Button Example

This example uses a window hook and button action procedure to implement a panel dialog with a Done button such that the panel can't be closed by clicking the panel's close widget, but can be closed by the Done button's action procedure:

```
Proc ShowDialog()
   PauseUpdate; Silent 1         // building window...
   NewPanel/N=Dialog/W=(225,105,525,305) as "Dialog"
   Button done,pos={119,150},size={50,20},title="Done"
   Button done,proc=DialogDoneButtonProc
   TitleBox warning,pos={131,83},size={20,20},title=""
   TitleBox warning,anchor=MC,fColor=(65535,16385,16385)
   SetWindow Dialog hook(dlog)=DialogHook, hookevents=2
EndMacro

Function DialogHook(s)
   STRUCT WMWinHookStruct &s
   Variable statusCode= 0
      strswitch( s.eventName )
      case "killVote":
         TitleBox warning win=$s.winName, title="Press the Done button!"
         Beep
         statusCode=2                  // prevent panel from being killed.
         break
      case "mousemoved":               // to reset the warning
         TitleBox warning win=$s.winName, title=""
         break
   endswitch
   return statusCode
End

Function DialogDoneButtonProc(ba) : ButtonControl
   STRUCT WMButtonAction &ba
   switch( ba.eventCode )
      case 2:              // mouse up
         // turn off the named window hook
         SetWindow $ba.win hook(dlog)=$""
         // kill the window AFTER this routine returns
         Execute/P/Q/Z "DoWindow/K "+ba.win
         break
   endswitch
   return 0
End
```

Window Hook Deactivate and Kill Events

The actions caused by these events (eventCode 2, 14, 15, 16 and 17) potentially affect multiple subwindows.

If you kill a subwindow, the root window's hook functions receives a subwindowKill event for that sub-window and any child subwindows.

If you kill a root window, the root window's hook function(s) receives a subwindowKill event for each child subwindow, and then the root window's hook function(s) receive a kill event.

Likewise, hiding and showing windows can result in subwindows being hidden or shown. In each case, the window hook function receives a hide or show event for each affected window or subwindow.

The winName member of WMWinHookStruct will be set to the full subwindow path of the subwindow that is affected.

Events for an exterior subwindow are a special case. See **Hook Functions for Exterior Subwindows** on page IV-285.

The hook functions attached to an exterior subwindow will receive a subwindowKill event if the exterior subwindow is killed as a result of killing the parent window. But it will receive a regular kill event if it is killed directly. Normal subwindows always receive only subwindowKill events.

The kill-related events are sent in this order when a window or subwindow is killed:

1. A killVote event is sent to the root window's hook function(s). If any hook function returns 2, no further events are generated and the window is not killed.
2. If the window is not a subwindow and wasn't created with /K=1, /K=2 or /K=3, the standard window close dialog appears. If the close is cancelled, the window is not killed, the window will receive an activate event when the dialog is dismissed, and no further events are generated. Otherwise, proceed to step 3.
3. If the window being killed has subwindows, starting from the bottom-most subwindow and working back toward the window being killed:

3a. If the subwindow is a panel, action procedures for controls contained in the subwindow are called with event -1, "control being killed".

3b. The root window's hook function(s) receive a subwindowKill event for the subwindow. If any hook function returns 1, no further subwindow hook events or control being killed events are sent, but the window killing process continues.

Steps 3a and 3b are repeated for each subwindow until the window or subwindow being killed is reached.

4. If the killed window is a root window, a kill event is sent to the root window's hook function(s). If any hook function returns 2, no further events are generated and the window is not killed. This method of preventing a window from closing is to be avoided: use the killVote event or the window-equivalent of `NewPanel/K=2`.

   Prior to Igor 7, you could return 2 when the window hook received a kill event to prevent the killing of the window. This is no longer supported. Use the killVote event instead.

There are several ways to prevent a window being killed. You might want to do this in order to enforce use of a Done or Do It button, or to prevent killing a control panel while some hardware action is taking place.

The best method is to use /K=2 when creating the window (see **Display** or **NewPanel**). Then the only way to kill the window is via the DoWindow/K command, or KillWindow command. In general, you would provide a button that kills the window after checking for any conditions that would prevent it.

The KillVote event is more flexible but harder to use. It gives your code a chance to decide whether or not killing is allowed. This means the user can close and kill the window with the window close box when it is allowed.

Returning 2 for the window kill event is not recommended. If you have old code that uses this method, we strongly recommend changing it to return 2 for the killVote event. New code should never return 2 for the kill event.

As of Igor Pro 7, returning 2 for the window kill event does not prevent the window from being killed. If you have old code that uses this technique, change it to return 2 for the killVote event instead.

Window Hook Show and Hide Events

Igor sends the show event to your hook function when the affected window is about to be shown but is still hidden. Likewise, Igor sends the hide event when the window is about to be hidden but is still visible. Other events, notably resize or move events, may be triggered by showing or hiding a window and may be sent before the change in visibility actually occurs. Here is an example that illustrates this issue:

```
Function MyHookFunction(s)
   STRUCT WMWinHookStruct &s

   strswitch(s.eventName)
      case "resize":
         GetWindow $(s.winName) hide
```

```
         if (V_value)
            Print "Resized while hidden"
         else
            Print "Resized while visible"
         endif
         break

      case "moved":
         GetWindow $(s.winName) hide
         if (V_value)
            Print "Moved while hidden"
         else
            Print "Moved while visible"
         endif
         break

      case "hide":
         print "Hide event"
         break

      case "show":
         print "Show event"
         break
   endswitch

   return 0    // Don't interfere with Igor's handling of events
End

Function MakePanelWithHook()
   NewPanel/N=MyPanel/HIDE=1
   SetWindow MyPanel, hook(myHook)=MyHookFunction
End
```

If you run the MakePanelWithHook function on the command line, you see nothing because the panel is hidden. Now select Windows→Other Windows→MyPanel. The following is printed in the history:

```
Show event
Moved while hidden
Resized while hidden
```

The hook function received the Move and Resize events *after* the Show event, but before the window actually became visible.

Hook Functions for Exterior Subwindows

A regular subwindow lives inside a host window and receives events through a hook function attached to its host window.

An exterior subwindow is different because, although it is a subwindow (it is controlled by a host window), unlike a regular subwindow, it has its own actual window and therefore you can attach a hook function directly to it. A hook function attached to the root window does not receive events for an exterior subwindow. To handle events for an exterior subwindow, you must attach a hook function to the exterior subwindow itself. For example:

```
// Make a panel
NewPanel/N=RootPanel

// Make an exterior subwindow attached to RootPanel
NewPanel/HOST=RootPanel/EXT=0

// Attach a hook function to the exterior subwindow
```

```
SetWindow RootPanel#P0 hook(myhook)=MyHookFunction
```

Unnamed Window Hook Functions

Unnamed window hook functions are supported for backward compatibility only. New code should use named window hook functions. See **Named Window Hook Functions** on page IV-277.

Each window can have one unnamed hook function. You designate a function as the unnamed window hook function using the **SetWindow** operation with the hook keyword.

The unnamed hook function is called when various window events take place. The reason for the hook function call is stored as an event code in the hook function's infoStr parameter.

The hook function is not called during experiment creation or load time so as to prevent the hook function from failing because the experiment is not fully recreated.

The hook function has the following syntax:

```
Function procName(infoStr)
   String infoStr
   String event= StringByKey("EVENT",infoStr)
   …
   return statusCode    // 0 if nothing done, else 1
End
```

`infoStr` is a string containing a semicolon-separated list of ***key*:*value*** pairs:

Key	Value
EVENT	*eventKey* See list of *eventKey* values below.
HCSPEC	Absolute path of the window or subwindow. See **Subwindow Command Concepts** on page III-87.
MODIFIERS	Bit flags as follows: Bit 0: Set if mouse button is down. Bit 1: Set if Shift is down. Bit 2: Set if Option (*Macintosh*) or Alt (*Windows*) is down. Bit 3: Set if Command (*Macintosh*) or Ctrl (*Windows*) is down. Bit 4: Contextual menu click: right-click or Control-click (*Macintosh*), or right-click (*Windows*). See **Setting Bit Parameters** on page IV-12 for details about bit settings.
OLDWINDOW	Previous name of the window or subwindow (for renamed event). Not the old absolute path *hcSpec*, just the name. WINDOW and HCSPEC contain the new name and new *hcSpec*.
WINDOW	Name of the window.

The value accompanying the EVENT keyword is one of the following:

eventKey	Meaning
activate	Window has just been activated.
copy	Copy menu item has been selected.

eventKey	Meaning
`cursormoved`	A graph cursor was moved. This event is sent only if bit 2 of the **SetWindow** operation hookevents flag is set.
`deactivate`	Window has just been deactivated.
`enablemenu`	Menus are being built and enabled.
`hide`	Window or subwindows about to be hidden.
`hideInfo`	The window info panel or window has just been hidden by **HideInfo**.
`hideTools`	The window tool palette or window has just been hidden by **HideTools**.
`kill`	Window is being killed. As of Igor Pro version 7, returning 2 as the hook function result no longer prevents Igor from killing the window. Use the killVote event instead.
`killVote`	Window is about to be killed. Return 2 to prevent that, otherwise return 0. See **Window Hook Deactivate and Kill Events** on page IV-283.
`menu`	A built-in menu item has been selected.
`modified`	A modification to the window has been made. This is sent to graph and notebook windows only. It is an error to try to kill a notebook window from the window hook during the modified event.
mousedown	Mouse button was clicked. This event is sent only if bit 0 of the **SetWindow** operation hookevents flag is set.
mousemoved	The mouse moved. This event is sent only if bit 1 of the **SetWindow** operation hookevents flag is set.
mouseup	Mouse button was released. This event is sent only if bit 0 of the **SetWindow** operation hookevents flag is set.
`moved`	Window has just been moved.
`renamed`	Window has just been renamed. The previous name is available under the OLDWINDOW key.
`resize`	Window has just been resized.
`show`	Window or subwindow is about to be unhidden.
`showInfo`	The window info panel or window has just been shown by **ShowInfo**.
`showTools`	The window tool palette or window has just been shown by **ShowTools**.
`subwindowKill`	One of the window's subwindows is about to be killed.

The modified event is issued only when a graph updates (See **DoUpdate**, **PauseUpdate**, and **ResumeUpdate**). Most changes to the graph are reported by the `modified` event, but not all: changing an annotation will not trigger the event, nor will adding, removing, or modifying a control or showing or hiding the drawing tools while using the /A flag. The modified event is not sent while a trace is being dragged or when the values of a trace's wave change (unless one the trace's axes is autoscaled). However, changing an axis range or indeed changing almost anything about axes or showing or hiding the info pane will send the modified event (only one event per graph update). When in doubt, use a print statement to determine when the event is sent.

If mouse events are enabled then the following key:value pairs will also be present in `infoStr`:

Key	Value
MOUSEX	X coordinate in pixels of the mouse.
MOUSEY	Y coordinate in pixels of the mouse.
TICKS	Time event happened.

Note that a mouseup event may or may not correspond to a previous mousedown. If the user clicks in the window, drags out and releases the button then the mouseup event will be missing. If the user clicks in another window, drags into this one and then releases then a mouseup will be sent that had no previous mousedown.

In the case of mousedown or mousemoved messages, a nonzero return value will skip normal processing of the message. This is most useful with mousedown.

The `cursormoved` event is not reported if Option (*Macintosh*) or Alt (*Windows*) is held down.

If the `cursormoved` event is enabled then the following key:value pairs will also be present in `infoStr`:

Key	Value
CURSOR	Name of the cursor that moved (A through J).
TNAME	Name of the trace the cursor is attached to (invalid if `ISFREE=1`).
ISFREE	1 if the cursor is “free” (not attached to a trace), 0 if it is attached to a trace or image.
POINT	Point number of the trace if not a free cursor. If the cursor is attached to an image, value is the row number of the image. If a free cursor, value is the fraction of the plot width, 0 being the left edge of the plot area, and 1 being the right edge.
YPOINT	Column number if the cursor is attached to an image, NaN if attached to a trace. If a free cursor, value is the fraction of the plot height, 0 being the top edge, and 1 being the bottom edge.

When the a menu event is reported then the following key:value pairs will also be present in `infoStr`:

Key	Value
MENUNAME	Name of menu (in English) as used by **SetIgorMenuMode**.
MENUITEM	Text of menu item as used by **SetIgorMenuMode**.

The `enablemenu` event does not pass `MENUNAME` or `MENUITEM`.

The `menu` and `enablemenu` messages are not sent when drawing tools are in use in a graph or layout or when waves are being edited in a graph.

Returning a value of 0 for the `enablemenu` message is recommended, though the return value is (currently) ignored.

You can use the **SetIgorMenuMode** operation to alter the enable state of Igor’s built-in menus in a way you find appropriate for the window. If you do this, usually you will also handle the menu message and perform your idea of an appropriate action.

Note: Dynamic user-defined menus (see **Dynamic Menu Items** on page IV-120) are built and enabled by using string functions in the menu definitions.

Returning a value of 0 for any menu message allows Igor to perform the normal action. Returning any other value (1 is commonly used) tells Igor to skip performing the normal action.

See the user function description with **IgorMenuHook** on page IV-273 for details on the sequence of menu building, enabling, and handling.

Custom Marker Hook Functions

You can define custom marker shapes for use with graph traces. To do this, you must define a custom marker hook function, activate it by calling SetWindow with the markerHook keyword, and set a trace to use it via the ModifyGraph operation marker keyword.

A custom marker hook function takes one parameter - a WMMarkerHookStruct structure. This structure provides your function with information you need to draw a marker.

The function prototype used with a custom marker hook has the format:

```
Function MyMarkerHook(s)
   STRUCT WMMarkerHookStruct &s
   <code to draw marker>
   ...
   return statusCode       // 0 if nothing done, else 1
End
```

Your function can use the DrawXXX operations to draw the marker. The function is called each time the marker is drawn and should not do anything other than drawing the marker. The function should return 1 if it handled the marker or 0 if not.

The marker number range, which you specify via the SetWindow markerHook call, can be any positive integers less than 1000 and can overlap built-in marker numbers.

WMMarkerHookStruct

The WMMarkerHookStruct structure has the following members:

WMMarkerHookStruct Structure Members

Member	Description
`Int32 usage`	0= normal draw, 1= legend draw (others reserved).
`Int32 marker`	Marker number minus start (i.e., starts from zero).
`float x,y`	Location of desired center of marker
`float size`	Half width/height of marker
`Int32 opaque`	1 if marker should be opaque
`float penThick`	Stroke width
`STRUCT RGBColor mrkRGB`	Fill color
`STRUCT RGBColor eraseRGB`	Background color
`STRUCT RGBColor penRG`	Stroke color
`WAVE ywave`	Trace's y wave
`double ywIndex`	Point number; ywave[wyIndex] is the y value where the marker is being drawn.

When your marker function is called, the pen thickness and colors of the drawing environment of the target window are already set consistent with the penThick, mrkRGB, eraseRGB and penRGB members.

Marker Hook Example

Here is an example that draws audiology symbols:

```
Function AudiologyMarkerProc(s)
	STRUCT WMMarkerHookStruct &s

	if( s.marker > 3 )
		return 0
	endif

	Variable size= s.size - s.penThick/2

	if( s.opaque )
		SetDrawEnv linethick=0,fillpat=-1
		DrawRect s.x-size,s.y-size,s.x+size,s.y+size
		SetDrawEnv linethick=s.penThick
	endif
	SetDrawEnv fillpat= 0		// polys are not filled

	if( s.marker == 0 )		// 90 deg U open to the right
		DrawPoly s.x+size,s.y-size,1,1,{size,-size,-size,-size,-size,size,size,size}
	elseif( s.marker == 1 )	// 90 deg U open to the left
		DrawPoly s.x-size,s.y-size,1,1,{-size,-size,size,-size,size,size,-size,size}
	elseif( s.marker == 2 )	// Cap Gamma
		DrawPoly s.x+size,s.y-size,1,1,{size,-size,-size,-size,-size,size}
	elseif( s.marker == 3 )	// Cap Gamma reversed
		DrawPoly s.x-size,s.y-size,1,1,{-size,-size,size,-size,size,size}
	endif
	return 1
End

Window Graph1() : Graph
	PauseUpdate; Silent 1		// building window...
	Make/O/N=10 testw=sin(x)
	Display /W=(35,44,430,252) testw,testw,testw,testw
	ModifyGraph offset(testw#1)={0,-0.2},offset(testw#2)={0,-0.4},
				offset(testw#3)={0,-0.6}
	ModifyGraph mode=3,marker(testw)=100,marker(testw#1)=101,marker(testw#2)=102,
				marker(testw#3)=103
	SetWindow kwTopWin,markerHook={AudiologyMarkerProc,100,103}
EndMacro
```

See also the Custom Markers Demo experiment - in Igor choose File→Example Experiments→Feature Demos 2→Custom Markers Demo.

Data Acquisition

Igor Pro provides a number of facilities to allow working with live data:

- Live mode traces in graphs
- FIFOs and Charts
- Background task
- External operations and external functions
- Controls and control panels
- User-defined functions

Live mode traces in graphs are useful when you acquiring complete waveforms in a single short operation and you want to update a graph many times per second to create an oscilloscope type display. See **Live Graphs and Oscilloscope Displays** on page II-259 for details.

FIFOs and Charts are used when you have a continuous stream of data that you want to capture and, perhaps, monitor. See **FIFOs and Charts** on page IV-291 details.

You can set up a background task that periodically performs data acquisition while allowing you to continue to work with Igor in the foreground. The background operations are *not* done using interrupts and therefore are easily disrupted by foreground operations. Background tasks are useful only for relatively infrequent tasks that can be quickly accomplished and do not cause a cascade of graph updates or other things that take a long time. See **Background Tasks** on page IV-298 for details.

You can create an instrument-like front panel for your data acquisition setup using user-defined controls in a panel window. Refer to Chapter III-14, **Controls and Control Panels**, for details. There are many example experiments that can be found in the Examples folder.

Igor Pro comes with an XOP named VDT2 for communicating with instruments via serial port (RS232), another XOP named NIGPIB2 for communicating via General Purpose Interface Bus (GPIB), and another XOP named VISA for communicating with VISA-compatible instruments. See the Igor Pro 7 Folder:More Extensions:Data Acquisition folder.

Sound I/O can be done using the built-in **SoundInRecord** and **PlaySound** operations.

The **NewCamera**, **GetCamera** and **ModifyCamera** operations support frame grabbing.

WaveMetrics produces the NIDAQ Tools software package for doing data acquisition using National Instruments cards. NIDAQ Tools is built on top of Igor using all of the techniques mentioned in this section. Information about NIDAQ Tools is available via the WaveMetrics Web site <http://www.wavemetrics.com/Products/NIDAQTools/nidaqtools.htm>.

Third parties have created data acquisition packages that use other hardware. Information about these is also available at <http://www.wavemetrics.com/Products/thirdparty.htm>.

If an XOP package is not available for your hardware you can write your own. For this, you will need to purchase the XOP Toolkit product from WaveMetrics. See **Creating Igor Extensions** on page IV-195 for details.

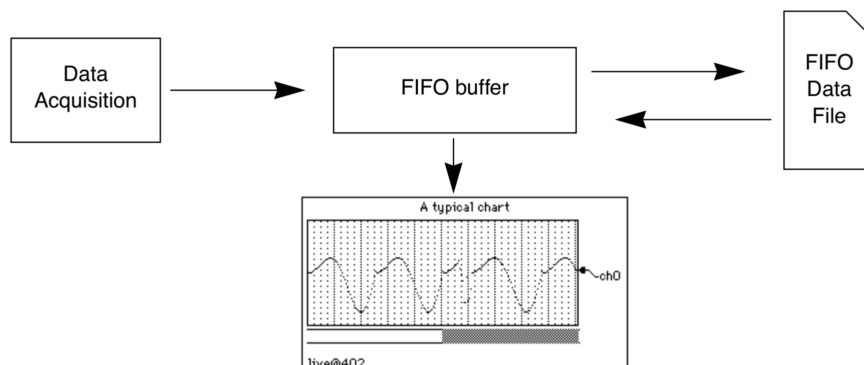
FIFOs and Charts

This section will be of interest principally to programmers writing data acquisition packages.

Most people who use FIFOs and chart recorder controls will do so via packages provided by expert Igor programmers. For information on using, as opposed to programming, chart controls, see **Using Chart Recorder Controls** on page IV-296.

FIFO Overview

A FIFO is an invisible data objects that can act as a First-In-First-Out buffer between a data source and a disk file. Data is placed in a FIFO either via the AddFIFOData operation or via an XOP package designed to interface to a particular piece of hardware. Chart recorder controls provide a graphical view of a portion of the data in a FIFO. When data acquisition is complete a FIFO can operate as a bidirectional buffer to a disk file. This allows the user to review the contents of a file by scrolling the chart "paper" back and forth. FIFOs can be used without a chart but charts have no use without a FIFO to monitor.

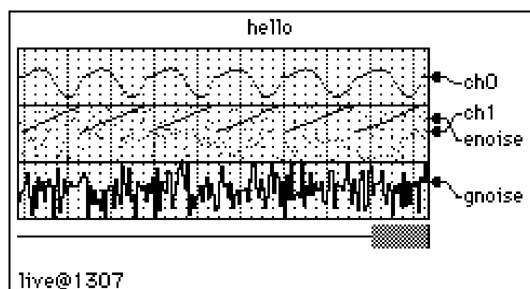


A FIFO can have an arbitrary number of channels each with its own number type, scaling, and units. All channels of a given FIFO share a common “timebase”.

Chart Recorder Overview

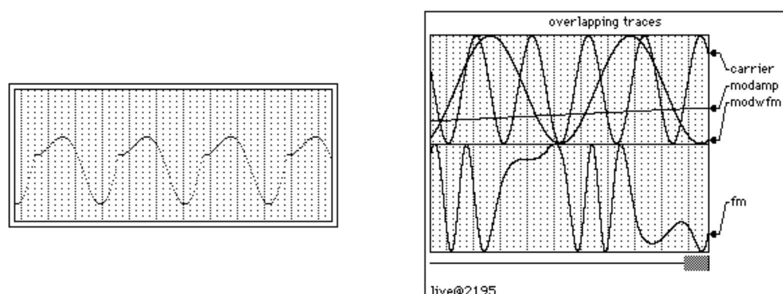
Chart recorder controls can be used to emulate a mechanical chart recorder that writes on paper with moving pens as the paper scrolls by under the pens. Charts can be used to monitor data acquisition processes or to examine a long data record. Although programming a chart is quite involved, using a chart is very easy.

Here is a typical chart recorder control:



The First-In-First-Out (FIFO) buffer is an invisible Igor component that buffers the data coming from data acquisition hardware and software and also writes the data to a file. The data that is streaming through the FIFO can be observed using a chart recorder control. When data acquisition is finished the process can be reversed with data coming back out of the file and into the FIFO where it can be reviewed using the chart. The FIFO file is optional but if missing then all data pushed out the end of the FIFO is lost.

Chart recorder controls can take on quite a number of forms from the simple to the sophisticated:



A given chart recorder control can monitor an arbitrary selection of channels from a single FIFO. Each trace can have its own display gain, color and line style and can either have its own area on the “paper” or can share an area with one or more other traces. There can be multiple chart recorder controls active an one time in one or more panel or graph windows.

Chart recorders can display an image strip when hooked up to a FIFO channel defined using the optional vectPnts parameter to NewFIFOChan. An example experiment, Image Strip FIFO Demo, is provided to illustrate how to use this feature.

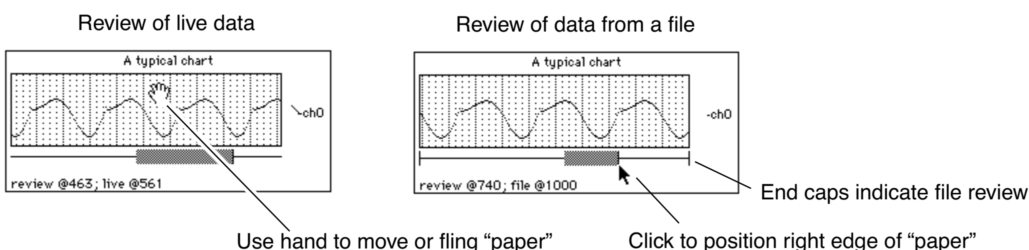
Chart recorders can operate in two modes — live and review. When a chart is in live mode and data acquisition is in progress, the chart "paper" scrolls by from right to left under the influence of the acquisition process. When in review mode, you are in control of the chart. When you position the mouse over the chart area you will see that the cursor turns into a hand. You can move the chart paper right or left by dragging with the hand. If you give the paper a push it will continue scrolling until it hits the end.

You can place the chart in review mode even as data acquisition is in progress by clicking in the paper with the hand cursor. To go back to live mode, give the paper a hard push to the left. When the paper hits the

end then the chart will go to into live mode. You can also go back to live mode by clicking anywhere in the margins of the chart.

Depending on the exact details of the data acquisition hardware and software you may run the risk of corrupting the data if you use review mode while acquisition is in progress. The person that created the hardware and software system you are using should have provided guidelines for the use of review mode during acquisition. In general, if the acquisition process is paced by hardware then it should be OK to use review mode.

In the chart recorder graphics above, you may have noticed the line directly under the scrolling paper area. This line represents the current extent of data while the gray bar represents the data that is being shown in the chart. The right edge of the gray bar represents the right edge of the section of data being shown in the chart window. The above example is shown in live mode. Here are two examples shown in review mode:



While data acquisition is in progress, the horizontal line represents the extent of the data in the FIFO's memory. After acquisition is over then the line includes all of the data in the FIFO's output file, if any.

If you are in review mode while data acquisition is taking place, you will notice that the gray bar indicates the view area is moving even though the paper appears to be motionless. This is because the FIFO is moving out from under the chart. Eventually it will reach a position where the chart display can not be valid since the data it wants to display has been flushed off the end of the FIFO. When this happens the view area will go blank. Because it is very time-consuming for Igor to try to keep the chart updated in this situation your data acquisition rate may suffer.

Chart recorder controls sometimes try to auto-configure themselves to match their FIFO. Generally this action is exactly what you want and is unobtrusive. Here are the rules that charts use:

When the FIFO becomes invalid or if it ceases to exist then the chart marks itself as being in auto-configure mode. If the FIFO then becomes valid the chart will read the FIFO information and configure itself to monitor all channels. It tries to set the ppStrip parameter to a value appropriate for the deltaT value of the FIFO. It does so by assuming a desirable update rate of around 10 strips per second. Thus, for example, if deltaT was 1 millisecond then ppStrip would be set to 100. The moral is: deltaT had better be valid or weird values of ppStrip may be created.

Any chart recorder channel configuration commands executed after the FIFO becomes invalid but before the FIFO becomes valid again will prevent auto-configuration from taking place.

Programming with FIFOs

You can create a FIFO by using the NewFIFO operation. When you are done using a FIFO you use the KillFIFO operation. A freshly created FIFO is not useful until either channels are created with the NewFIFOChan operation or until the FIFO is attached to a disk file for review using a variant of the CtrlFIFO operation.

You can obtain information about a FIFO using the FIFOStatus operation and you can extract data from a FIFO using the FIFO2Wave operation. Once a FIFO is set up and ready to accept data, you can insert data using the AddFIFOData operation. Alternately, you can insert data using an XOP package.

Once data is stored in a file you can review the data using a FIFO or extract data using user-defined functions. See the example experiment, “FIFO File Parse”, for sample utility routines.

Here are the operations and functions used in FIFO programming:

NewFIFO	**KillFIFO**
NewFIFOChan	**CtrlFIFO**
FIFO2Wave	**AddFIFOData**
AddFIFOVectData	**FIFOStatus**

As with background tasks, FIFOs are considered transient objects — they are not saved and restored as part of an experiment.

A FIFO does not need to be attached to a file to be useful. Note, however, that the oldest data is lost when a FIFO overflows.

A FIFO set up to acquire data does not become valid until the start command is issued. Chart controls will report invalid FIFOs on their status line. FIFO2Wave will give an error if it is invoked on an invalid FIFO. A stopped FIFO remains valid until the first command is issued that could potentially change the FIFO's setup.

Data in a running FIFO is written to disk when Igor notices that the FIFO is half full or when the AddFIFOData command is issued and the FIFO is full. The amount of time it takes to write data to disk can be quite considerable and at the same time unpredictable. If the computer disk cache size is large then writes to disk will be less frequent but when they do occur they will take a long time. This will matter to you most if you are attempting to take data rapidly using software, perhaps using an Igor background task.

If you are taking data via interrupt transfer to an intermediate buffer of adequate size or if your hardware has an adequate internal buffer then the disk write latency may not be a concern. If dead time due to disk writes is a concern then you may want to decrease the size of the disk cache and you may want to run with a relatively small FIFO. Note that if you change the size of the disk cache you may have to reboot for the change to take effect.

When the stop command is given to a running FIFO then it goes into review mode and remains valid. If the FIFO is attached to a file then the entire contents of the file can be reviewed or be transferred to a wave using the FIFO2Wave command.

The act of attaching a FIFO to an existing file for review using the rfile keyword of the CtrlFIFO command reads in the file contents and sets itself up for review. You should not use the NewFIFOChan command or any of the other CtrlFIFO keywords except size. Here is all that is required to review a preexisting file:

```
Variable refnum
Open/R/P=mypath refnum as "my file"
NewFIFO dave
CtrlFIFO dave,rfile=refnum
```

If any chart controls have been set up to monitor FIFO dave then they will automatically configure themselves to display all the channels of dave using default parameters.

The connection between FIFOs and chart controls relies on Igor's dependency manager. The dependency manager does not automatically run during function execution — you have to explicitly call it by executing the DoUpdate command.

The dependency manager sends messages to a chart control when:

- A FIFO is created
- A FIFO is killed
- A FIFO becomes valid (start command)
- Data is added to a FIFO

In particular, if inside a user function, you kill a FIFO and then create it again you should call DoUpdate after the kill so that the chart control notices the kill and can get ready for the creation.

FIFO File Format

This information is for users who may wish to create FIFO files with their own programs or for those who need to analyze data stored in a FIFO file. You will need to have a reading familiarity with the C programming language to understand the following. Note, the following information may be out of date. For the most up to date information, refer to the most recent version of the auxiliary file named NamedFIFO.h located in the “Miscellaneous:More Documentation:” folder.

Consider the following data structures….

```
#define CUR_FIFOFILE_VERSION 0

typedef struct FIFOFIleHeader{
   long typeP1,typeP2;        // 'IGOR','fifo'
   long version;              // CUR_FIFOFILE_VERSION
   long datasize; // bytes of data following ChartChunkInfo field if known
   long hsize;    // size of following ChartChunkInfo field; data follows
}FIFOFIleHeader;

#define MAX_NOTESIZE 255
#define FIFO_CHAN_VERSION_NUM 0x01

typedef struct ChartChanInfo{
   long ntype;                   // number type -- NT_FP32 or NT_I16 or ...
   double offset,gain;           // result= (measval-offset)*gain
   double fsPlus,fsMinus;        // value of + & - full scale
   char name[MAX_OBJ_NAME+1];    // name of this channel
   char units[4];                // SU abbrev of units
   long chanRefcon;              // for use by data acquisition sw
}ChartChanInfo;

typedef struct ChartChunkInfo{
   long type;              // 'chrt'
   short version;                // version number of this data structure
   short pad1;                   // maintain 32 bit allignment
   unsigned long startDate;      // datetime of start command
   char note[MAX_NOTESIZE+1];    // room for a short note from user
   double deltaT;    // data acquisition speed (if known, in seconds)
   long xopRefcon;               // for use by data acquisition sw
   long nchan;                   // number of channels
   ChartChanInfo info[];         // info for each channel
}ChartChunkInfo;
```

The FIFO file consists of the FIFOFileHeader followed by the ChartChunkInfo and finally by chunks of data until the end of the file. It is expected that the format of this file will undergo evolutionary changes. You should be prepared to keep up with such changes. In particular you should always check for the proper version numbers when trying to interpret such a file.

An example of a user-defined function that can parse a FIFO file can be found in:

```
Igor Pro Folder:Examples:Programming:FIFO File Parse.pxp
```

The vectpnts field allows FIFO channels to contain a vector of data rather than just a single data point.

Igor also supports a split file FIFO header:

```
#define CUR_FIFOSplitFILE_VERSION (CUR_FIFOFILE_VERSION+1)
typedef struct FIFOSplitFIleHeader{
   long typeP1,typeP2;           // 'IGOR','fifo'
   long version;                 // CUR_FIFOSplitFILE_VERSION

   /*
   ** The split file header differs from the unified by the
   ** insertion of the following 3 fields.
```

```
   */
   char datafile[256];            // c-string containing name of file
                                  // containing actual data
   long dataoffset;               // offset into data file
   long dsize;                    // number of bytes of data or zero
                                  // to use entire rest of file

   long datasize;                 // bytes of data following ChartChunkInfo
                                  // field if known
   long hsize;                    // size of following ChartChunkInfo field;
                                  // data follows that
}FIFOSplitFIleHeader;
```

This format allows the raw data to reside in its own file rather than having to be in the same file as the header. This was provided to allow the review of large binary files generated by third-party programs.

Another way to use a FIFO and chart control to review a raw binary file is to use the rdfile keyword with the CtrlFIFO command.

See the example experiment, Wave Review Chart Demo, for sample code for both the split header and raw binary formats.

FIFO and Chart Demos

```
Igor Pro Folder:Examples:Feature Demos:FIFO Chart Demo FM.pxp
Igor Pro Folder:Examples:Feature Demos:FIFO Chart Overhead.pxp
Igor Pro Folder:Examples:Feature Demos:Wave Review Chart Demo.pxp
Igor Pro Folder:Examples:Imaging:Image Strip FIFO Demo.pxp
```

Using Chart Recorder Controls

The information provided here pertains to using rather than programming a chart recorder control. For information on programming chart controls, see **FIFOs and Charts** on page IV-291.

An Igor chart recorder control works in conjunction with a FIFO to display data as it is acquired or to review data that has previously been acquired.

Chart Reorder Control Basics

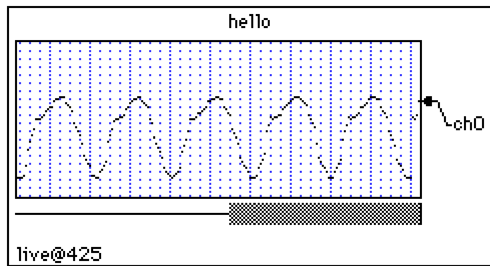
An Igor chart recorder control is neither an analytical tool nor a presentation quality graphic. It is meant only for real time monitoring of incoming data or to review data from a FIFO file. When you want an analytical or presentation quality graph you must transfer the data to a wave and then use a conventional Igor graph.

An Igor chart recorder control emulates a mechanical chart recorder that writes on paper with moving pens as the paper scrolls by under the pens. It differs from a real chart recorder in that the paper of the latter moves at a constant velocity whereas the “paper” of an Igor chart moves only when data becomes available in the FIFO it is monitoring. If data is placed in the FIFO at a constant rate then the “paper” will scroll by at a constant rate. However, since there can be no guarantee that the data is coming in at a constant rate, we refer to the horizontal axis not in terms of time but rather in terms of data sample number.

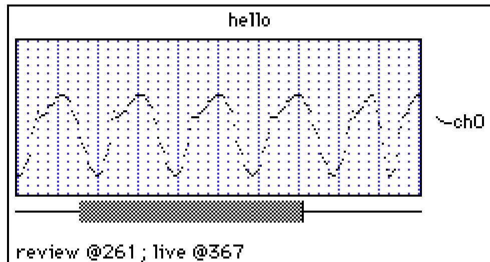
A given chart recorder control can monitor an arbitrary selection of channels from a single FIFO. Each chart trace can have its own display gain, color and line style and can either have its own area on the “paper” or can share an area with one or more other traces. There can be multiple charts active an one time in one or more control panel or graph windows.

Operating a Chart Recorder

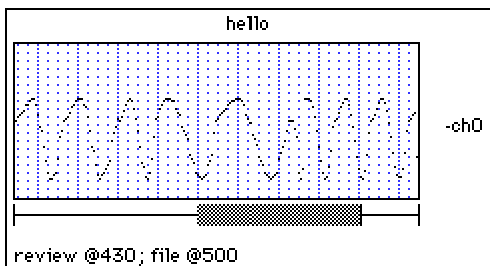
Here is a typical chart recorder while taking data:



And here is the same chart recorder while reviewing data even though data acquisition is still taking place:



And here we are while reviewing data from the file after data acquisition is complete:



Notice the positioning strip just under the chart and above the status line. It consists of a horizontal line and a horizontal, gray bar. The line, called the positioning line, represents the extent of available data. The bar, called the positioning bar, represents the currently displayed region of this data.

While data acquisition is in progress, the available data is the data in the FIFO's memory. After the acquisition is over then the available data includes all of the data in the FIFO's output file, if any. The vertical bars at the ends of the positioning line indicate we are reviewing from a file.

You can instantly jump to any portion of the data by clicking on the positioning line. The spot that you click on indicates the part of the available data that you want to view. After clicking you can drag the "paper" region around.

The chart recorder will be in one of two modes: live mode or review mode. While data acquisition is under way, the chart recorder will display incoming data if it is in live mode. If it is in review mode, you can review previously acquired data.

Clicking on the positioning line or in the positioning bar puts the chart recorder into review mode even if data acquisition is taking place. To exit review mode and go into live mode, simply click anywhere in the chart recorder outside of the "paper" and the positioning strip. Of course, if you are not acquiring data you can not go into live mode.

Another way to go into review mode and navigate is to grab the "paper" with the mouse and fling it to the left or right. It will keep going until it hits the end of available data. The speed at which the "paper" moves depends on how hard you fling it.

If you are in review mode while data acquisition is taking place, you will notice that the positioning bar indicates the view area is moving even though the "paper" appears to be motionless. This is because the FIFO is moving out from under the chart. Eventually it will reach a position where the chart display can not be valid since the data it wants to display has been flushed off the end of the FIFO. When this happens the paper will go blank. Because it is very time consuming for Igor to try to keep the chart updated in this situation, your data acquisition rate may suffer. To get an idea of what kind of data rates can be sustained using an Igor background task, spend some time experimenting with the "FIFO/Chart Overhead" example experiment.

Chart Recorder Control Demos

```
Igor Pro Folder:Examples:Feature Demos:FIFO Chart Demo FM.pxp
Igor Pro Folder:Examples:Feature Demos:FIFO Chart Overhead.pxp
Igor Pro Folder:Examples:Feature Demos:Wave Review Chart Demo.pxp
Igor Pro Folder:Examples:Imaging:Image Strip FIFO Demo.pxp
```

Background Tasks

Background tasks allow procedures to run periodically "in the background" while you continue to interact normally with Igor. This is useful for data acquisition, simulations and other processes that run indefinitely, over long periods of time, or need to run at regular intervals. Using a background task allows you to continue to interact with Igor while your data acquisition or simulation runs.

Originally Igor supported just one unnamed background task controlled using the **CtrlBackground** operation (page V-100). New code should use the **CtrlNamedBackground** operation (page V-101) to create named background tasks instead, as shown in the following sections. You can run any number of named backgrounds tasks.

In addition to the documentation provided here, the Background Task Demo experiment provides sample code that is designed to be redeployed for other projects. We recommend reading this documentation first and then opening the demo by choosing File→Example Experiments→Programming→Background Task Demo.

Background Task Example #1

You create and control background tasks using the **CtrlNamedBackground** operation. The main parameters of CtrlNamedBackground are the background task name, the name of a procedure to be called periodically, and the period. Here is a simple example:

```
Function TestTask(s)     // This is the function that will be called periodically
   STRUCT WMBackgroundStruct &s

   Printf "Task %s called, ticks=%d\r", s.name, s.curRunTicks
   return 0              // Continue background task
End

Function StartTestTask()
   Variable numTicks = 2 * 60    // Run every two seconds (120 ticks)
   CtrlNamedBackground Test, period=numTicks, proc=TestTask
   CtrlNamedBackground Test, start
End

Function StopTestTask()
   CtrlNamedBackground Test, stop
End
```

You start this background task by calling `StartTestTask()` from the command line or from another procedure. StartTestTask creates a background task named Test, sets the period which is specified in units of

ticks (1 tick = 1/60th of a second), and specifies the user-defined function to be called periodically (TestTask in this example).

You stop the Test background task by calling `StopTestTask()`.

As shown above, the background procedure takes a **WMBackgroundStruct** parameter. In most cases you won't need to access it.

Background Task Exit Code

The background procedure (TestTask in the example above) returns an exit code to Igor. The code is one of the following values:

0: The background procedure executed normally.

1: The background procedure wants to stop the background task.

2: The background procedure encountered an error and wants to stop the background task.

Normally the background procedure should return 0 and the background task will continue to run. If you return a non-zero value, Igor stops the background task. You can tell Igor to terminate the background task by returning the value 1 from the background function.

If you forget to add a return statement to your background procedure, this acts like a non-zero return value and stops the background task.

Background Task Period

The CtrlNamedBackground operation's period keyword takes an integer parameter expressed in ticks. A tick is approximately 1/60th of a second. Thus the timing of Igor background tasks has a nominal resolution of 1/60th of a second.

You can override the specified period in the background task procedure by writing to the nextRunTicks field of the **WMBackgroundStruct** structure. This is needed only if you want your procedure to run at irregular intervals.

The actual time between calls to the background procedure is not guaranteed. Igor runs the background task from its outer loop, when Igor is doing nothing else. If you do something in Igor that takes a long time, for example performing a lengthy curve fit, running a user-defined function that takes a long time, or saving a large experiment, Igor's outer loop does not run so the background task will not run. If you do something that causes a compilation of Igor procedures to fail, the background task is not called. On Macintosh, the background task is not called while a menu is displayed or while the mouse button is pressed.

If you need your background task to continue running even if you edit other procedures in Igor, you need to make your project an independent module. See **Independent Modules** on page IV-224 for details.

If you need precise timing that can not be interrupted, things get much more complicated. You need to do your data acquisition in an Igor thread running in an independent module or in a thread created by an XOP that you write. See **ThreadSafe Functions and Multitasking** on page IV-308 for details.

The shortest supported period is one tick. The minimum actual period for the background task depends on your hardware and what your background task is doing. If you set the period too low for your background task, interacting with Igor becomes sluggish.

It is very easy to bog your computer down using background tasks. If the background task takes a long time to execute or if it triggers something that takes a long time (like a wave dependency formula or updating a complex graph) then it may appear that the system is hung. It is not, but it may take longer to respond to user actions than you are willing to wait.

Background Task Limitations

The principal limitation of Igor background tasks is that they are stopped while other operations are taking place. Thus, although you can type commands into the command line without disrupting the background task, when you press Return the task is stopped until execution of the command line is finished.

Background tasks do not run if procedures are in an uncompiled state. If you need your background task to continue running even if you edit other procedures in Igor, you need to make your project an independent module. See **Independent Modules** on page IV-224 for details.

On Macintosh, the background task does not run when the mouse button is pressed or when a menu is displayed.

Background Tasks and Errors

If a background task procedure contains a bug, it will typically generate an error each time the procedure runs. Normally an error generates an error dialog. If this happened over and over again, it would prevent you from fixing the bug.

Igor handles such repeated errors as follows: The first time an error occurs during the execution of the background task procedure, Igor displays an error dialog. On subsequent errors, Igor prints an error message in the history. After printing 10 such error messages, Igor stops printing messages. When you click a control, execute a command from the command line or execute a command through a menu item, the process starts over.

If the Igor debugger is enabled and Debug on Error is turned on, Igor will break into the debugger each time an error occurs in the background task procedure. You may have to turn Debug on Error off to give you time to stop the background task. You can do this from within the debugger by right-clicking.

Background Tasks and Dialogs

By default, a background task created by CtrlNamedBackground continues to run while a dialog is displayed. You can change this behavior using the CtrlNamedBackground dialogsOK keyword.

If you allow background tasks to run while an Igor dialog is present, you should ensure that your background task does not kill anything that a dialog might depend on. It should not kill waves or variables. It should never directly modify a window (except for a status panel) and especially should never remove something from a window (such as a trace from a graph). Otherwise your background task may kill something that the dialog depends on which will cause a crash.

Background Task Tips

Background tasks should be designed to execute quickly. They do not run in separate threads threads and they hang Igor's event processing as long as they run. For maximum responsiveness, your task procedure should take no more than a fraction of a second to run even when the period is long. If you have to perform a lengthy computation, let the user know what is going on, perhaps via a message in a status control panel.

Background tasks should never attempt to put up dialogs or directly wait for user input. If you need to get the attention of the user, you should design your system to include a status control panel with an area for messages or some other change in appearance. If you need to wait for the user, you should do so by monitoring global variables set by nonbackground code such as a button procedure in a panel.

Your task procedure should always leave the current data folder unchanged on exit.

Background Task Example #2

Here is an example that uses many of the concepts discussed above. The task prints a message in the history area at one second intervals five times, performs a “lengthy calculation”, and then waits for the user to give the go-ahead for another run.

The task does its own timing and consequently is set to run at the maximum rate (60 times per second). The task procedure, MyBGTask, tests to see if one second has elapsed since the last time it printed a message. In a real application, you might test to see if some external event has occurred.

To try the example, copy the code below to the Procedure window and execute:

```
BGDemo()

Function BGDemo()
	DoWindow/F BGDemoPanel			// bring panel to front if it exists
	if( V_Flag != 0 )
		return 0					// panel already exists
	endif

	String dfSav= GetDataFolderDFR()		// so we can leave current DF as we found it
	NewDataFolder/O/S root:Packages
	NewDataFolder/O/S root:Packages:MyDemo	// our variables go here

	// still here if no panel, create globals if needed
	if( NumVarOrDefault("inited",0) == 0 )
		Variable/G inited= 1

		Variable/G lastRunTicks= 0 // value of ticks function last time we ran
		Variable/G runNumber= 0			// incremented each time we run
		// message displayed in panel using SetVariable...
		String/G message="Task paused. Click Start to resume."

		Variable/G running=0				// when set, we do our thing
	endif

	SetDataFolder dfSav
	NewPanel /W=(150,50,449,163)
	DoWindow/C BGDemoPanel				// set panel name
	Button StartButton,pos={21,12},size={50,20},proc=BGStartStopProc,title="Start"
	SetVariable msg,pos={21,43},size={300,17},title=" ",frame=0
	SetVariable msg,limits={-Inf,Inf,1},value= root:Packages:MyDemo:message
End

Function MyBGTask(s)
	STRUCT WMBackgroundStruct &s

	NVAR running= root:Packages:MyDemo:running

	if( running == 0 )
		return 0					// not running -- wait for user
	endif

	NVAR lastRunTicks= root:Packages:MyDemo:lastRunTicks

	if( (lastRunTicks+60) >= ticks )
		return 0					// not time yet, wait
	endif

	NVAR runNumber= root:Packages:MyDemo:runNumber

	runNumber += 1

	printf "Hello from the background, #%d\r",runNumber

	if( runNumber >= 5 )
		runNumber= 0
		running= 0					// turn ourself off after five runs

		// run again when user says to
		Button StopButton,win=BGDemoPanel,rename=StartButton,title="Start"

		// Simulate a long calculation after a run
		String/G root:Packages:MyDemo:message="Performing long calculation. Please wait."
		ControlUpdate /W=BGDemoPanel msg
		DoUpdate /W=BGDemoPanel			// Required on Macintosh for control to be redrawn
```

```
		Variable t0= ticks
		do
			if (GetKeyState(0) & 32)
				Print "Lengthy process aborted by Escape key"
				break
			endif
		while( ticks < (t0+60*3) )	// delay for 3 seconds

		String/G root:Packages:MyDemo:message="Task paused. Click Start to resume."
	endif

	lastRunTicks= ticks

	return 0
End

Function BGStartStopProc(ctrlName) : ButtonControl
	String ctrlName

	NVAR running= root:Packages:MyDemo:running
	if( CmpStr(ctrlName,"StartButton") == 0 )
		running= 1
		Button $ctrlName,rename=StopButton,title="Stop"
		String/G root:Packages:MyDemo:message=""
		CtrlNamedBackground MyBGTask, proc=MyBGTask, period=1, start
	endif
	if( CmpStr(ctrlName,"StopButton") == 0 )
		running= 0
		Button $ctrlName,rename=StartButton,title="Start"
		CtrlNamedBackground MyBGTask, stop
		String/G root:Packages:MyDemo:message="Task paused. Press Start to resume."
	endif
End
```

Background Task Example #3

For another example including code that you can easily redeploy for your own project, open the Background Task Demo experiment by choosing File→Example Experiments→Programming→Background Task Demo.

Old Background Task Techniques

Originally Igor supported just one unnamed background task. This is still supported for backward compatibility but new code should use CtrlNamedBackground to create and control named background tasks instead.

The unnamed background task is designated using **SetBackground**, controlled using **CtrlBackground** and killed using **KillBackground**. The **BackgroundInfo** operation returns information about the unnamed background task.

The SetBackground, CtrlBackground, KillBackground and BackgroundInfo operations work only with the unnamed background task. For named background tasks, the CtrlNamedBackground operation provides all necessary functionality.

By default, a background task created by CtrlBackground does not run while a dialog is displayed. You can change this behavior using the CtrlBackground dialogsOK keyword.

Automatic Parallel Processing with TBB

TBB stands for “Threading Building Blocks”. It is an Intel technology that facilitates the use of multiple processors on a given task. The home page for TBB is:

https://www.threadingbuildingblocks.org

Starting with Igor Pro 7, some Igor operations, such as CurveFit, DSPPeriodogram, and ImageProfile, automatically use TBB. To see which operations use TBB, choose Help→Command Help, click Show All, and then check the Automatically Multithreaded Only checkbox.

You don't need to do anything to take advantage of automatic multithreading with TBB. It happens automatically.

Running on multiple threads reduces the time required for number crunching tasks when the benefit of using multiple processors exceeds the overhead. Operations that use TBB automatically use multiple threads only when the size of the data or the complexity of the problem crosses a certain threshold. Igor is programmed to use a reasonable threshold for each supported operation. You can control the threshold using the **MultiThreadingControl** operation.

Automatic Parallel Processing with MultiThread

Intermediate-level Igor programmers can make use of multiple processors to speed up wave assignment statements in user-defined functions. To do this, simply insert the keyword MultiThread in front of a normal wave assignment. For example, in a function:

```
Make wave1
Variable a=4
MultiThread wave1= sin(x/a)
```

The expression, on the right side of the assignment statement, is compiled as threadsafe even if the host function is not.

Because of the overhead of spawning threads, you should use MultiThread only when the destination has a large number of points or the expression takes a significant amount of time to evaluate. Otherwise, you may see a performance penalty rather than an improvement.

The assignment is automatically parceled into as many threads as there are processors, each evaluating the right-hand expression for a different output point.

The MultiThread keyword causes Igor to evaluate the expression for multiple output points simultaneously. Do not make any assumptions as to the order of processing and certainly do not try to use a point from the destination wave other than the current point in the expression. For example, do not do something like this:

```
wave1 = wave1[p+1] - wave1[p-1]   // Result is indeterminate
```

Expressions like give unexpected results even in the absence of threading.

Here is a simple example to try on your own machine:

```
Function TestMultiThread(n)
   Variable n                    // Number of wave points

   Make/O/N=(n) testWave

   // To prime processor data cache so comparison will be valid
   testWave= 0

   Variable t1,t2
   Variable timerRefNum

   // First, non-threaded
   timerRefNum = StartMSTimer
   testWave= sin(x/8)
   t1= StopMSTimer(timerRefNum)

   // Now, automatically threaded
   timerRefNum = StartMSTimer
   MultiThread testWave= sin(x/8)
   t2= StopMSTimer(timerRefNum)
```

```
   Variable processors = ThreadProcessorCount
   Print "On a machine with",processors,"cores,MultiThread is", t1/t2,"faster"
End
```

Here is the output on a Mac Pro:

```
•TestMultiThread(100)
  On a machine with  8  cores, MultiThread is  0.059746  faster

•TestMultiThread(10000)
  On a machine with  8  cores, MultiThread is  3.4779  faster

•TestMultiThread(1000000)
  On a machine with  8  cores, MultiThread is  6.72999  faster

•TestMultiThread(10000000)
  On a machine with  8  cores, MultiThread is  8.11069  faster
```

The first result shows that the MultiThread keyword slowed the assignment down. This is because the assignment involved a small number of points and MultiThread has some overhead.

The remaining results illustrate that MultiThread can provide increased speed for assignments involving large waves.

In the last result, the speed improvement factor was greater than the number of processors. This is explained by the fact that, once running, a threadsafe expression has slightly less overhead than a normal expression.

If the right-hand expression involves calling user-defined functions, those functions must be threadsafe (see **ThreadSafe Functions** on page IV-97) and must also follow these rules:

1. Do not do anything to waves that are passed as parameters that might disturb memory. For example, do not change the number of points in the wave or change its data type or kill it or write to a text wave.
2. Do not write to a variable that is passed by reference.
3. Note that any waves or global variables created by the function will disappear when then wave assignment is finished.
4. Each thread has its own private data folder tree. You can not use WAVE, NVAR or SVAR to access objects in the main thread.

Failure to heed rule #1 will likely result in a crash.

Although it is legal to use the MultiThread mechanism in a threadsafe function that is already running in a preemptive thread via **ThreadStart**, it is not recommended and will likely result in a substantial loss of speed.

For an example using MultiThread, open the Mandelbrot demo experiment file by choosing "File→Example Experiments→Programming→MultiThreadMandelbrot".

Data Folder Reference MultiThread Example

Advanced programmers can use waves containing data folder references and wave references along with MultiThread to perform multithreaded calculations more involved than evaluating an arithmetic expression. Here we use **Free Data Folders** (see page IV-88) to facilitate multithreading.

In this example, we extract each of the planes of a 3D wave, perform a filtering operation on the planes, and then finally assemble the planes into an output 3D wave. The main function, Test, executes a multithreaded assignment statement where the expression includes a call to a subroutine named Worker.

Because MultiThread is used, multiple instances of Worker execute simultaneously on different cores. Each instance runs in its own thread, working on a different plane. Each instance returns one filtered plane in a wave named M_ImagePlane in a thread-specific free data folder. The use of free data folders allows each instance of Worker to work on its own M_ImagePlane wave without creating a name conflict.

When the multithreaded assignment is finished, the main function assembles an output 3D wave by concatenating the filtered planes.

```
// Extracts a plane from the 3D input wave, filters it, and returns the
// filtered output as M_ImagePlane in a new free data folder
ThreadSafe Function/DF Worker(w3DIn, plane)
   WAVE w3DIn
   Variable plane

   DFREF dfSav= GetDataFolderDFR()

   // Create a free data folder to hold the extracted and filtered plane
   DFREF dfFree= NewFreeDataFolder()
   SetDataFolder dfFree

   // Extract the plane from the input wave into M_ImagePlane.
   // M_ImagePlane is created in the current data folder
   // which is a free data folder.
   ImageTransform/P=(plane) getPlane, w3DIn
   Wave M_ImagePlane             // Created by ImageTransform getPlane

   // Filter the plane
   WAVE wOut= M_ImagePlane
   MatrixFilter/N=21 gauss,wOut

   SetDataFolder dfSav

   // Return a reference to the free data folder containing M_ImagePlane
   return dfFree
End

Function Demo(numPlanes)
   Variable numPlanes

   // Create a 3D wave and fill it with data
   Make/O/N=(200,200,numPlanes) src3D= (p==(2*r))*(q==(2*r))

   // Create a wave to hold data folder references returned by Worker.
   // /DF specifies the data type of the wave as "data folder reference".
   Make/DF/N=(numPlanes) dfw

   Variable timerRefNum = StartMSTimer

   MultiThread dfw= Worker(src3D,p)

   Variable elapsedTime = StopMSTimer(timerRefNum) / 1E6

   Printf "Statement took %g seconds for %d planes\r", elapsedTime, numPlanes

   // At this point, dfw holds data folder references to 50 free
   // data folders created by Worker. Each free data folder holds the
   // extracted and filtered data for one plane of the source 3D wave.

   // Create an output wave named out3D by cloning the first filtered plane
   DFREF df= dfw[0]
   Duplicate/O df:M_ImagePlane, out3D

   // Concatenate the remaining filtered planes onto out3D
   Variable i
   for(i=1; i<numPlanes; i+=1)
      df= dfw[i]     // Get a reference to the next free data folder
```

```
		Concatenate {df:M_ImagePlane}, out3D
	endfor

	// dfw holds references to the free data folders. By killing dfw,
	// we kill the last reference to the free data folders which causes
	// them to be automatically deleted. Because there are no remaining
	// references to the various M_ImagePlane waves, they too are
	// automatically deleted.
	KillWaves dfw
End
```

To run the demo, execute:

```
Demo(50)
```

On an eight-core Mac Pro, this took 4.1 seconds with the MultiThread keyword and 0.6 seconds without the MultiThread keyword for a speedup of about 6.8 times.

Wave Reference MultiThread Example

In the preceding example, free data folders were used to hold data processed by threads. Since each free data folder held just a single wave, the example can be simplified by using free waves instead of free data folders. So here we perform the same threaded filtering of planes using free waves.

Because MultiThread is used, multiple instances of Worker execute simultaneously on different cores. Each instance runs in its own thread, working on a different plane. Each instance returns one filtered plane in a free wave named M_ImagePlane. The use of free waves allows each instance of Worker to work on its own M_ImagePlane wave without creating a name conflict.

This version of the example relies on the fact that a wave in a free data folder becomes a free wave when the free data folder is automatically deleted. See **Free Wave Lifetime** on page IV-86 for details.

```
ThreadSafe Function/WAVE Worker(w3DIn, plane)
	WAVE w3DIn
	Variable plane

	DFREF dfSav= GetDataFolderDFR()

	// Create a free data folder and set it as the current data folder
	SetDataFolder NewFreeDataFolder()

	// Extract the plane from the input wave into M_ImagePlane.
	// M_ImagePlane is created in the current data folder
	// which is a free data folder.
	ImageTransform/P=(plane) getPlane, w3DIn
	Wave M_ImagePlane			// Created by ImageTransform getPlane

	// Filter the plane
	WAVE wOut= M_ImagePlane
	MatrixFilter/N=21 gauss,wOut

	// Restore the current data folder
	SetDataFolder dfSav

	// Since the only reference to the free data folder created above
	// was the current data folder, there are now no references it.
	// Therefore, Igor has automatically deleted it.
	// Since there IS a reference to the M_ImagePlane wave in the free
	// data folder, M_ImagePlane is not deleted but becomes a free wave.

	return wOut		// Return a reference to the free M_ImagePlane wave
End
```

```
Function Demo(numPlanes)
   Variable numPlanes

   // Create a 3D wave and fill it with data
   Make/O/N=(200,200,numPlanes) srcData= (p==(2*r))*(q==(2*r))

   // Create a wave to hold data folder references returned by Worker.
   // /WAVE specifies the data type of the wave as "wave reference".
   Make/WAVE/N=(numPlanes) ww

   Variable timerRefNum = StartMSTimer

   MultiThread ww= Worker(srcData,p)

   Variable elapsedTime = StopMSTimer(timerRefNum) / 1E6

   Printf "Statement took %g seconds for %d planes\r", elapsedTime, numPlanes

   // At this point, ww holds wave references to 50 M_ImagePlane free waves
   // created by Worker. Each M_ImagePlane holds the extracted and filtered
   // data for one plane of the source 3D wave.

   // Create an output wave named out3D by cloning the first filtered plane
   WAVE w= ww[0]
   Duplicate/O w, out3D

   // Concatenate the remaining filtered planes onto out3D
   Variable i
   for(i=1;i<numPlanes;i+=1)
      WAVE w= ww[i]
      Concatenate {w}, out3D
   endfor

   // ww holds references to the free waves. By killing ww, we kill
   // the last reference to the free waves which causes them to be
   // automatically deleted.
   KillWaves ww
End
```

To run the demo, execute:

```
Demo(50)
```

Structure Array MultiThread Example

In a preceding example, free data folders were used to hold data processed by threads. A somewhat simpler approach is to use one or more structures to pass input data and to receive output data. The following example uses a single structure for both input and output. An array of these structures stored in a wave ensures that each thread works on its own data. After the calculation, the results are extracted. The net result for this simple example is nothing more than: `dataOutput = sin(p)`.

```
Structure ThreadIOData
   // Input to thread
   double x

   // Output from thread
   double out
EndStructure

Function Demo()
   if (IgorVersion() < 6.36)
```

```
      // This example crashes in Igor Pro 6.35 or before
      // because of a bug in StructGet/StructPut
      Abort "Function requires Igor Pro 6.36 or later."
   endif

   STRUCT ThreadIOData ioData

   // Prepare input
   Make/O ioDataArray      // This wave will be redimensioned by StructPut
   Variable i, imax=100
   for(i=0; i<imax; i+=1)
      ioData.x = i                        // Set input data
      StructPut ioData, ioDataArray[i]    // Pack structure into wave column
   endfor

   // Generate output
   Make/O/N=(imax) threadOutput
   MultiThread threadOutput = Worker(ioDataArray, p)

   // Extract output
   Make/O/N=(imax) outputData
   for(i=0; i<imax; i+=1)
      StructGet ioData, ioDataArray[i]
      outputData[i] = ioData.out
   endfor

   KillWaves ioDataArray, threadOutput
End

ThreadSafe Function Worker(w, point)
   WAVE w
   Variable point

   STRUCT ThreadIOData ioData
   StructGet ioData, w[point]       // Extract structure from wave column

   ioData.out = sin(ioData.x)       // Calculate of output data

   StructPut ioData, w[point]       // Pack structure into wave column

   // The return value from the thread worker function is accessible
   // via ThreadReturnValue. It is not used in this example.
   return point
End
```

To run the demo, execute:

```
Demo()
```

ThreadSafe Functions and Multitasking

Igor supports two multitasking techniques that are easy to use:

- **Automatic Parallel Processing with TBB**
- **Automatic Parallel Processing with MultiThread**

This section discusses the third technique, **ThreadSafe Functions**, which expert programmers can use to create complex, preemptive multitasking background tasks.

Preemptive multitasking uses the following functions and operations:

ThreadProcessorCount	**ThreadGroupCreate**
ThreadStart	**ThreadGroupPutDF**
ThreadGroupGetDF (deprecated)	**ThreadGroupGetDFR**
ThreadGroupWait	**ThreadReturnValue**
ThreadGroupRelease	

To run a threadsafe function preemptively, you first create a thread group using **ThreadGroupCreate** and then call **ThreadStart** to start your worker function. Usually you will use the same function for each thread of a group although they can be different.

The worker function must be defined as threadsafe and must return a real or complex numeric result. The return value can be obtained after the function finishes by calling **ThreadReturnValue**.

The worker function can take variable and wave parameters. It can not take pass-by-reference parameters or data folder reference parameters.

Any waves you pass to the worker are accessible to both the main thread and to your preemptive thread. Such waves are marked as being in use by a thread and Igor will refuse to perform any operations that could change the size of the wave.

You can determine if any threads of a group are still running by calling **ThreadGroupWait**. Use zero for the "milliseconds to wait" parameter to just test if all threads are finished. Use a larger value to cause the main thread to sleep until all threads are finished. If you know the maximum time the threads should take, you can use that value and print an error message or take other action if the threads don't finish in time.

When ThreadGroupWait is called, Igor updates certain internal variables including variables that track whether a thread has finished and what result it returned. Therefore you must call ThreadGroupWait before calling ThreadReturnValue.

Once you are finished with a given thread group, call **ThreadGroupRelease**.

The Igor debugger can not be used with preemptive threads. You will need to use print statements for debugging.

The hard part of using multithreading is devising a scheme for partitioning your data processing algorithms into threads.

Thread Data Environment

When a thread is started, Igor creates a root data folder for that thread. This root data folder and any data objects that the thread creates in it are private to the thread. This constitutes a separate data hierarchy for each thread.

Data is transferred, when you request it, from the main thread to a preemptive thread and vice-versa using input and output queues. The "currency" of these queues is the data folder, which provides considerable flexibility for passing data to threads and for retrieving results. Each thread group has an input queue to which the main thread may post data and an output queue from which the main thread may retrieve results.

The terms "input" and "output" are relative to the preemptive thread. The main thread posts a data folder to the input queue to send input to the preemptive thread. The preemptive thread retrieves the data folder from the input queue. After processing, the preemptive thread may post a data folder to the output queue. The main thread reads output from the preemptive thread by retrieving the data folder from the output queue.

Use **ThreadGroupPutDF** to post data folders and **ThreadGroupGetDFR** to retrieve them. These are called from both the main thread and from preemptive threads.

ThreadGroupPutDF clips the specified data folder, and everything it contains, out of the source thread's data hierarchy and puts it in the queue. From the standpoint of the source thread, it is as if KillDataFolder had been called. While a data folder resides in a queue, it is not accessible by any thread. See the documentation for **ThreadGroupPutDF** for some warnings about its use.

ThreadGroupGetDFR removes the data folder from the queue and returns it, as a free data folder, to the calling thread. Because it is a free data folder, Igor will automatically delete it when there are no more references to it, for example, when the thread returns.

Except for waves passed to the thread worker function as parameters and the thread worker's return value, the input and output queues are the only way for a thread to share data with the main thread. Examples below illustrate the use of these queues.

Parallel Processing - Group-at-a-Time Method

In this example, we attempt to improve the speed of filling columns of a 2D wave with a sin function. The traditional method is compared with parallel processing. Notice how much more complicated the multi-threaded version, MTFillWave, is compared to the single threaded STFillWave.

```
ThreadSafe Function MyWorkerFunc(w,col)
	WAVE w
	Variable col

	w[][col]= sin(x/(col+1))

	return stopMSTimer(-2)			// Time when we finished
End

Function MTFillWave(dest)
	WAVE dest

	Variable ncol= DimSize(dest,1)
	Variable i,col,nthreads= ThreadProcessorCount
	Variable threadGroupID= ThreadGroupCreate(nthreads)

	for(col=0; col<ncol;)
		for(i=0; i<nthreads; i+=1)
			ThreadStart threadGroupID,i,MyWorkerFunc(dest,col)
			col+=1
			if( col>=ncol )
				break
			endif
		endfor

		do
			Variable threadGroupStatus= ThreadGroupWait(threadGroupID,100)
		while( threadGroupStatus != 0 )
	endfor
	Variable dummy= ThreadGroupRelease(threadGroupID)
End

Function STFillWave(dest)
	WAVE dest

	Variable ncol= DimSize(dest,1)
	Variable col

	for(col= 0;col<ncol;col+=1)
		MyWorkerFunc(dest,col)
	endfor
End

Function ThreadTest(rows)
	Variable rows

	Variable cols=10

	make/o/n=(rows,cols) jack

	Variable i
```

```
	for(i=0;i<10;i+=1)		// get any pending pause events out of the way
	endfor

	Variable ttime= stopMSTimer(-2)

	Variable t0= stopMSTimer(-2)
	MTFillWave(jack)
	Variable t1= stopMSTimer(-2)
	STFillWave(jack)
	Variable t2= stopMSTimer(-2)

	ttime= (stopMSTimer(-2) - ttime)*1e-6

	// Times are in microseconds
	printf "ST: %d, MT: %d; ",t2-t1,t1-t0
	printf "speed up factor: %.3g; total time= %.3gs\r",(t2-t1)/(t1-t0),ttime
End
```

The empty loop above is necessary because of periodic pauses in execution when Igor checks for user aborts. If a pause was pending, we want to get it out of the way beforehand to avoid it affecting the first timing test.

After starting Igor Pro, there is initially some extra overhead associated with creating new threads. Consequently, in the test results to follow, the first test is run twice.

Results for Mac Mini 1.66 GHz Core Duo, OS X 10.4.6:

```
•ThreadTest(100)
  ST: 223, MT: 1192; speed up factor: 0.187; total time= 0.00146s
•ThreadTest(100)
  ST: 211, MT: 884; speed up factor: 0.239; total time= 0.0011s
•ThreadTest(1000)
  ST: 1991, MT: 1821; speed up factor: 1.09; total time= 0.00381s
•ThreadTest(10000)
  ST: 19857, MT: 11921; speed up factor: 1.67; total time= 0.0318s
•ThreadTest(100000)
  ST: 199174, MT: 113701; speed up factor: 1.75; total time= 0.313s
•ThreadTest(1000000)
  ST: 2009948, MT: 1146113; speed up factor: 1.75; total time= 3.16s
```

As you can see, when there is sufficient work to be done, the speed up factor approaches the theoretical maximum of 2 for dual processors.

Now on the same computer but booting into Windows XP Pro:

```
•ThreadTest(100)
  ST: 245, MT: 523; speed up factor: 0.468; total time= 0.000776s
•ThreadTest(100)
  ST: 399, MT: 247; speed up factor: 1.61; total time= 0.000655s
•ThreadTest(1000)
  ST: 3526, MT: 1148; speed up factor: 3.07; total time= 0.00468s
•ThreadTest(10000)
  ST: 34830, MT: 10467; speed up factor: 3.33; total time= 0.0453s
•ThreadTest(100000)
  ST: 350253, MT: 99298; speed up factor: 3.53; total time= 0.45s
•ThreadTest(1000000)
  ST: 2837645, MT: 1057275; speed up factor: 2.68; total time= 3.89s
```

So, what is happening here? The speed-up factors for Windows XP are greater than for Mac OS X, but mostly because the ST version is much slower. We do not known why the ST version runs more slowly — the Benchmark 2.01 example experiment shows similar values for OS X vs. XP on this same computer.

Parallel Processing - Thread-at-a-Time Method

In the previous section, we dispatched a group of threads, waited for them to all finish, and then dispatched another group of threads. Using that technique, a slow thread in the group would cause all of the group's threads to wait.

In this section, we dispatch a thread anytime there is a free thread in the group. This technique requires Igor Pro 6.23 or later.

The only thing that changes from the preceding example is that the MTFillWave function is replaced with this MTFillWaveThreadAtATime function:

```
Function MTFillWaveThreadAtATime(dest)
   WAVE dest

   Variable ncol= DimSize(dest,1)
   Variable col,nthreads= ThreadProcessorCount
   Variable threadGroupID= ThreadGroupCreate(nthreads)
   Variable dummy

   for(col=0; col<ncol; col+=1)
      // Get index of a free thread - Requires Igor Pro 6.23 or later
      Variable threadIndex = ThreadGroupWait(threadGroupID,-2) - 1
      if (threadIndex < 0)
         dummy = ThreadGroupWait(threadGroupID, 50)// Let threads run a while
         col -= 1                    // Try again for the same column
         continue                    // No free threads yet
      endif
      ThreadStart threadGroupID, threadIndex, MyWorkerFunc(dest,col)
   endfor

   // Wait for all threads to finish
   do
      Variable threadGroupStatus = ThreadGroupWait(threadGroupID,100)
   while(threadGroupStatus != 0)

   dummy = ThreadGroupRelease(threadGroupID)
End
```

The ThreadGroupWait statement suspends the main thread for a while so that the preemptive threads get more processor time. The parameter 50 is the number of milliseconds to wait. You should tune this for your application.

Input/Output Queues

In this example, data folders containing a data wave and a string variable that specifies the task to be performed are created and posted to the thread group's input queue. The thread worker function waits for an input data folder to become available. It then processes the input and posts an output data folder to the thread group's output queue from which it is retrieved by the main thread.

```
ThreadSafe Function MyWorkerFunc()
   do
      do
         DFREF dfr = ThreadGroupGetDFR(0,1000)// Get free data folder from input queue
         if (DataFolderRefStatus(dfr) == 0)
            if( GetRTError(2) ) // New in 6.20 to allow this distinction:
               Print "worker closing down due to group release"
            else
               Print "worker thread still waiting for input queue"
            endif
         else
            break
         endif
      while(1)

      SVAR todo = dfr:todo
      WAVE jack = dfr:jack

      NewDataFolder/S outDF

      Duplicate jack,outw // WARNING: outw must be cleared. See WAVEClear below
      String/G did= todo
      if( CmpStr(todo,"sin") )
         outw= sin(outw)
      else
```

```
            outw= cos(outw)
        endif

        // Clear outw so Duplicate above does not try to use it and to allow
        // ThreadGroupPutDF to succeed.
        WAVEClear outw

        ThreadGroupPutDF 0,:    // Put current data folder in output queue

        KillDataFolder dfr      // We are done with the input data folder
    while(1)

    return 0
End

Function DemoThreadQueue()
    Variable i,ntries= 5,nthreads= 2

    Variable/G threadGroupID = ThreadGroupCreate(nthreads)

    for(i=0;i<nthreads;i+=1)
        ThreadStart threadGroupID,i,MyWorkerFunc()
    endfor

    for(i=0;i<ntries;i+=1)
        NewDataFolder/S forThread
        String/G todo
        if( mod(i,3) == 0 )
            todo= "sin"
        else
            todo= "cos"
        endif
        Make/N= 5 jack= x + gnoise(0.1)

        WAVEClear jack

        ThreadGroupPutDF threadGroupID,: // Send current data folder to input queue
    endfor

    for(i=0;i<ntries;i+=1)
        do
            // Get results in free data folder
            DFREF dfr= ThreadGroupGetDFR(threadGroupID,1000)
            if ( DatafolderRefStatus(dfr) == 0 )
                Print "Main still waiting for worker thread results."
            else
                break
            endif
        while(1)

        SVAR did = dfr:did
        WAVE outw = dfr:outw

        Print "task= ",did,"results= ",outw

        // The next two statements are not really needed as the same action
        // will happen the next time through the loop or, for the last iteration,
        // when this function returns.
        WAVEClear outw      // Redundant because of the WAVE statement above
        KillDataFolder dfr  // Redundant because dfr refers to a free data folder
    endfor

    // This terminates the MyWorkerFunc by setting an abort flag
    Variable tstatus= ThreadGroupRelease(threadGroupID)
    if( tstatus == -2 )
        Print "Thread would not quit normally, had to force kill it. Restart Igor."
    endif
End
```

Typical output:

```
•DemoThreadQueue()
    task=   sin  results=
outw[0]= {0.994567,0.660904,-0.516692,-0.996884,-0.63106}
    task=   cos  results=
```

```
outw[0]= {0.0786631,0.709576,0.873524,0.0586175,-0.718122}
   task=   cos  results=
outw[0]= {-0.23686,0.848603,0.871922,0.0992451,-0.856209}
   task=   sin  results=
outw[0]= {0.999734,0.531563,-0.172071,-0.931296,-0.750942}
   task=   cos  results=
outw[0]= {-0.166893,0.767707,0.925874,0.114511,-0.662994}
   worker closing down due to group release
   worker closing down due to group release
```

Parallel Processing With Large Datasets

In the preceding section we synthesized the input data. In the real-world, your input data would most-likely be in an existing wave and you would have to copy it to a data folder to put into the input queue.

If your input data is very large, for example, a 3D stack of images, copying would require too much memory. In that case, a good choice is to pass the input directly to the thread using parameters to the thread worker function and use the output queue to return output to the main thread.

To do this you can use the **Parallel Processing - Thread-at-a-Time Method** and the output queue to return results.

Preemptive Background Task

In this example, we create a single worker thread that runs while the user does other things. A normal cooperative background task retrieves results from the preemptive thread. Although the background task will sometimes be blocked (as described in **Background Tasks** on page IV-298) the preemptive worker thread will always be running or waiting for data.

Another example of this kind of multitasking can be found in the “Slow Data Acq” demo experiment referenced under **More Multitasking Examples** on page IV-316.

In some cases, it may be possible to run two instances of Igor instead of using a preemptive background task. Running two instances is far simpler, so use that approach if it is feasible.

We put the code for the background tasks in an independent module (see **The IndependentModule Pragma** on page IV-51) so that the user can recompile procedures, which is done automatically when a recreation macro is created, without stopping the background task.

You might use a preemptive background task is when you have lengthy computations but want to continue to do other things, such as creating graphics for publication. Although you can do anything you want while the task runs in the experiment, if you load a different experiment, the thread is killed.

For this example, our “lengthy computation” is simply creating a wave of sine values which is not lengthy at all and consequently there is no reason for using a preemptive thread in this case. To simulate a lengthy computation, the code delays for a few seconds before posting its results.

The named background task checks the output queue every 10 ticks, when it is not blocked, and updates a graph with data retrieved from the queue.

Independent modules can not be defined in the built-in procedure window so paste the following code in a new procedure window:

```
#pragma IndependentModule= PreemptiveExample

ThreadSafe Function MyWorkerFunc()
   do
      DFREF dfr = ThreadGroupGetDFR(0,inf)
      if( DataFolderRefStatus(dfr) == 0 )
         return -1              // Thread is being killed
      endif

      WAVE frequencies = dfr:frequencies   // Array of frequencies to calculate
      Variable i, n= numpnts(frequencies)

      for(i=0;i<n;i+=1)
```

```
			NewDataFolder/S resultsDF
			Make jack= sin(frequencies[i]*x)

			Variable t0= ticks
			do
				// waste cpu for a few seconds
			while(ticks < (t0+120))

			// ThreadGroupPutDF requires that no waves in the data folder be referenced
			WAVEClear jack

			ThreadGroupPutDF 0,:			// Send current data folder to input queue
		endfor

		KillDataFolder dfr		// We are done with the input data folder
	while(1)

	return 0
End

Function DisplayResults(s)		// Called from cooperative background task
	STRUCT WMBackgroundStruct &s

	DFREF dfSav= GetDataFolderDFR()

	SetDataFolder root:testdf
	NVAR threadGroupID
	DFREF dfr = ThreadGroupGetDFR(threadGroupID,0) // Get free data folder from queue
	if( DataFolderRefStatus(dfr) != 0 )
		// Make free data folder a regular data folder in root:testdf
		MoveDataFolder dfr, :

	// Give data folder a unique name
		String dfName = UniqueName("Results", 11, 0)
		RenameDataFolder dfr, $dfName

		WAVE jack = dfr:jack		// This is the output from the thread
		AppendToGraph/W=ThreadResultsGraph jack
	endif

	SetDataFolder dfSav
	return 0
End
```

And put this in the main procedure window:

```
Function DemoPreemptiveBackgroundTask()
	DFREF dfSav= GetDataFolderDFR()

	NewDataFolder/O/S root:testdf // thread group ID and result datafolders go here

	variable/G threadGroupID= ThreadGroupCreate(1)

	ThreadStart threadGroupID,0,PreemptiveExample#MyWorkerFunc()

	// MyWorkerFunc is now running and waiting for input data
	// now, let's give it something to do
	NewDataFolder/S tasks
	Make/N=10 frequencies= 1/(10+p/2+enoise(0.2))// array of frequencies to calculate
	WAVEClear frequencies

	ThreadGroupPutDF threadGroupID,:		// thread is now crunching away

	// Results will be appended to this graph
	Display /N=ThreadResultsGraph as "Thread Results"

	// ...by this named task
	CtrlNamedBackground ThreadResultsTask,period=10,proc=PreemptiveExample#DisplayResults,start

	SetDataFolder dfSav		// restore current df
End

Function PostMoreFreqs()
	NVAR threadGroupID = root:testdf:threadGroupID

	NewDataFolder/S moretasks
	Make/N=50 frequencies= 1/(15+p/2+enoise(0.2))  // array of frequencies to calculate
	WAVEClear frequencies
```

```
   ThreadGroupPutDF threadGroupID,:              // thread continues crunching
End
```

Open the Data Browser and then, on the command line, execute:

```
DemoPreemptiveBackgroundTask()
```

After the action stops, send more tasks to the background thread by executing

```
PostMoreFreqs()
```

While this is running, experiment with creating graphs, using dialogs, creating functions, etc. Note that both tasks run indefinitely.

To start over you need to stop the preemptive background task, stop the named background task, kill the graph, and delete the data. This function, which you can paste into the main procedure window, will do it.

```
Function StopDemo()
   NVAR threadGroupID = root:testdf:threadGroupID

   // Stop preemptive thread
   Variable status = ThreadGroupRelease(threadGroupID)

   // Stop named background task
   CtrlNamedBackground ThreadResultsTask, stop

   // Kill graph
   DoWindow /K ThreadResultsGraph

   // Kill data
   KillDataFolder root:testdf
End
```

More Multitasking Examples

More multitasking examples can be found in the following example experiments:

The Multithreaded LoadWave demo experiment in “Igor Pro 7 Folder/Examples/Programming”.

The Multithreaded Mandelbrot demo experiment in “Igor Pro 7 Folder/Examples/Programming”.

The Multiple Fits in Threads demo experiment in Igor “Pro Folder/Examples/Curve Fitting”.

The Slow Data Acq demo experiment in “Igor Pro 7 Folder/Examples/Programming”.

The Thread-at-a-Time demo experiment in “Igor Pro 7 Folder/Examples/Programming”.

Cursors — Moving Cursor Calls Function

You can write a hook function which Igor calls whenever a cursor is moved.

Graph-Specific Cursor Moved Hook

The preferred way to do this is to use SetWindow to designate a window hook function for a specific graph window (see **Window Hook Functions** on page IV-276). In your window hook function, look for the cursormoved event. Your hook function receives a **WMWinHookStruct** structure containing fields that describe the cursor and its properties.

For a demo of this technique, choose File→Example Experiments→Techniques→Cursor Moved Hook Demo.

Global Cursor Moved Hook

This section describes an old technique in which you create a hook function that is called any time a cursor is moved in any graph. This technique is more difficult to implement and kludgy, so it is no longer recommended.

You can write a hook function named CursorMovedHook. Igor automatically calls it whenever any cursor is moved in any graph, unless Option (*Macintosh*) or Alt (*Windows*) is pressed.

The CursorMovedHook function takes one string argument containing information about the graph, trace or image, and cursor in the following format:

```
GRAPH:graphName;CURSOR:<A - J>;TNAME:traceName; MODIFIERS:modifierNum;
ISFREE:freeNum;POINT:xPointNumber; [YPOINT:yPointNumber;]
```

The *traceName* value is the name of the graph trace or image to which the cursor is attached.

The *modifierNum* value represents the state of some of the keyboard keys summed together:

1 If Command (*Macintosh*) or Ctrl (*Windows*) is pressed.

2 If Control (*Macintosh only*) is pressed.

4 If Shift is pressed.

8 If Caps Lock is pressed.

The Option key (*Macintosh*) or Alt key (*Windows*) is not represented because it prevents the hook from being called.

The YPOINT keyword and value are present only when the cursor is attached to a two-dimensional item such as an image, contour, or waterfall plot or when the cursor is free.

If cursor is free, POINT and YPOINT values are fractional relative positions (see description in **Cursor** operation on page V-103). If TNAME is empty, fields POINT, ISFREE and YPOINT are not present.

This example hook function simply prints the information in the history area:

```
Function CursorMovedHook(info)
   String info
   Print info
End
```

Whenever any cursor on any graph is moved, this CursorMovedHook function will print something like the following in the history area:

```
GRAPH:Graph0;CURSOR:A;TNAME:jack;MODIFIERS:0;ISFREE:0;POINT:6;
```

Cursor Globals

On older technique involving globals named S_CursorAInfo and S_CursorBInfo is no longer recommended. For details, see the “Cursor Globals” subtopic in the Igor6 help files.

Profiling Igor Procedures

You can find bottlenecks in your procedures using profiling.

Profiling is supported by the FunctionProfiling.ipf file. To use it, add this to your procedures:

```
#include <FunctionProfiling
```

Then choose Windows→Procedures→FunctionProfiling.ipf and read the instructions in the file.

Crashes

A crash results from a software bug and prevents a program from continuing to run. Crashes are highly annoying at best and, at worst, can cause you to lose valuable work.

WaveMetrics uses careful programming practices and extensive testing to make Igor as reliable and bug-free as we can. However in Igor as in any complex piece of software it is impossible to exterminate all bugs. Also, crashes can sometimes occur in Igor because of bugs in other software, such as printer drivers, video drivers or system extensions.

We are committed to keeping Igor a solid and reliable program. If you experience a crash, we would like to know about it.

When reporting a crash to WaveMetrics, please start by choosing Help-Contact Support. This provides us with important information such as your Igor version and your OS version.

Please include the following in your report:

- A description of what actions preceded the crash and whether it is reproducible.
- A recipe for reproducing the crash, if possible.
- A crash log (described below), if possible.

In most cases, to fix a crash, we need to be able to reproduce it.

Crash Logs on Mac OS X

When a crash occurs on Mac OS X, most of the time the system is able to generate a crash log. You can usually find it at:

```
/Users/<user>/Library/Logs/DiagnosticReports/Igor Pro_<date>_<machinename>.crash
```

where <user> is your user name.

The /Users/<user>/Library folder is hidden. To reveal the DiagnosticReports folder:

1. Choose Finder->Go to Folder
2. Enter ~/Library/Logs/DiagnosticReports
3. Click Go

Send this log as an attachment when reporting a crash.

Crashes On Windows

When a crash occurs on Windows, Igor attempts to write a crash report that may help WaveMetrics determine and fix the cause of the crash. If Igor is able to write a crash report, it displays a dialog showing the location of the crash report on disk. The location is in your Igor preferences folder and will be something like:

```
C:\Users\<user>\AppData\Roaming\WaveMetrics\Igor Pro 7\Diagnostics\Igor Crash Reports.txt
```

If the "Igor Crash Reports.txt" file already exists when a crash occurs, Igor appends a new report to the existing file.

Igor may also write a minidump file to the same folder. A minidump file, which has a ".dmp" extension, contains additional information about the crash. There will typically be one minidump file for each crash.

When a crash occurs, Igor attempts to open the Diagnostics folder on your desktop to make it easy for you to find the report and minidump files.

Please send the "Igor Crash Reports.txt" file, along with the minidump files related to the current crash, as email attachments to WaveMetrics support. If possible, include instructions for reproducing the crash and any other details that may help us understand what you were doing leading to the crash.

Once the problem has been resolved, if you want to reduce clutter and reclaim disk space, you can delete the Diagnostics folder and its contents. Igor will recreate the folder if necessary.

There may be cases where Igor is not able to write a crash report. This would happen if a library, security software or the operating system has overridden Igor's crash handler for some reason.