WinDriver™ PCI/ISA User's Manual

Jungo Connectivity Ltd.

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WinDriver™ PCI/ISA User's Manual

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Chapter 1
WinDriver Overview

In this chapter you will explore the uses of WinDriver, and learn the basic steps of creating your driver.

This manual outlines WinDriver's support for PCI/ISA/EISA/CompactPCI/PCI Express devices.
WinDriver also supports the Universal Serial Bus (**USB**). For detailed information regarding WinDriver USB, please refer to the WinDriver product page on our web site (https://www.jungo.com/st/products/windriver/) and to the **WinDriver USB Manual**, which is available online at https://www.jungo.com/st/support/windriver/.

1.1. Introduction to WinDriver

WinDriver is a development toolkit that dramatically simplifies the difficult task of creating device drivers and hardware-access applications. WinDriver includes a wizard and code generation features that automatically detect your hardware and generate the driver to access it from your application. The driver and application you develop using WinDriver are source code compatible across all supported operating systems [1.7]. The driver is binary compatible across Windows 10/Server 2016/8.1/Server 2012 R2/8/Server 2012/7/Server 2008 R2/Server 2008.

Bus architecture support includes PCI//ISA/EISA/CompactPCI/PCI Express.
ISA, and EISA are supported on Windows, and Linux.

WinDriver provides a complete solution for creating high-performance drivers.

Don't let the size of this manual fool you. WinDriver makes developing device drivers an easy task that takes hours instead of months. Most of this manual deals with the features that WinDriver offers to the advanced user. However, most developers will find that reading this chapter and glancing through the DriverWizard and function-reference chapters is all they need to successfully write their driver.

WinDriver supports development for all PCI/ISA/EISA/CompactPCI/PCI Express chipsets, and offers enhanced support for specific chipsets, as outlined in Chapter 7.

Chapter 10 explains how to tune your driver code to achieve optimal performance, with special emphasis on WinDriver's Kernel PlugIn feature. This feature allows the developer to write and debug the entire device driver in the user mode, and later drop performance critical portions of the code into kernel mode. In this way the driver achieves optimal kernel-mode performance, while the developer need not sacrifice the ease of user-mode development. For a detailed overview of the Kernel PlugIn, refer to Chapters 11–12.

Visit Jungo's web site at https://www.jungo.com for the latest news about WinDriver and other driver development tools that Jungo offers.

1.2. Background

1.2.1. The Challenge

In protected operating systems such as Windows and Linux, a programmer cannot access hardware directly from the application level (user mode), where development work is usually done. Hardware can only be accessed from within the operating system itself (kernel mode or Ring-0), utilizing software modules called device drivers. In order to access a custom hardware device from the application level, a programmer must do the following:

- Learn the internals of the operating system he is working on.
- Learn how to write a device driver.
- Learn new tools for developing/debugging in kernel mode (WDK, ETK, DDI/DKI).
- Write the kernel-mode device driver that does the basic hardware input/output.
- Write the application in user mode that accesses the hardware through the device driver written in kernel mode.
- Repeat the first four steps for each new operating system on which the code should run.

1.2.2. The WinDriver Solution

- **Easy Development** — WinDriver enables Windows, and Linux programmers to create PCI/ISA/EISA/CompactPCI/PCI Express based device drivers in an extremely short time. WinDriver allows you to create your driver in the familiar user-mode environment, using MS Visual Studio, C++, GCC, Windows GCC, or any other appropriate compiler or development environment. You do not need to have any device-driver knowledge, nor do you have to be familiar with operating system internals, kernel programming, the WDK, ETK or DDI/DKI.
- **Cross Platform** — The driver created with WinDriver will run on Windows 10/Server 2016/8.1/Server 2012 R2/8/Server 2012/7/Server 2008 R2/Server 2008, Windows 10 IoT/ Embedded Windows 8.1/8/7, and Linux. In other words — write it once, run it on many platforms.
- **Friendly Wizards** — DriverWizard (included) is a graphical diagnostics tool that lets you view /define the device's resources and test the communication with the hardware with just a few mouse clicks, before writing a single line of code. Once the device is operating to your satisfaction, DriverWizard creates the skeletal driver source code, giving access-functions to all the resources on the hardware.

- **Kernel-Mode Performance** — WinDriver's API is optimized for performance. For drivers that need kernel-mode performance, WinDriver offers the Kernel PlugIn. This powerful feature enables you to create and debug your code in user mode and run the performance-critical parts of your code (such as the interrupt handling or access to I/O mapped memory ranges) in kernel mode, thereby achieving kernel-mode performance (zero performance degradation). This unique feature allows the developer to run user-mode code in the OS kernel without having to learn how the kernel works. For a detailed overview of this feature, see Chapter 11.

1.3. How Fast Can WinDriver Go?

You can expect the same throughput using the WinDriver Kernel PlugIn as when using a custom kernel driver. Throughput is constrained only by the limitations of your operating system and hardware. A rough estimate of the throughput you can obtain using the Kernel PlugIn is approximately 100,000 interrupts per second.

1.4. Conclusion

Using WinDriver, a developer need only do the following to create an application that accesses the custom hardware:

- Start DriverWizard and detect the hardware and its resources.
- Automatically generate the device-driver code from within DriverWizard, or use one of the WinDriver samples as the basis for the application (see Chapter 7 for an overview of WinDriver's enhanced support for specific chipsets).
- Modify the user-mode application, as needed, using the generated/sample functions, to implement the desired functionality for your application.

Your hardware-access application will run on all the supported platforms [1.7] — just recompile the code for the target platform. The code is binary-compatible across Windows 10/Server 2016/8.1/Server 2012 R2/8/Server 2012/7/Server 2008 R2/Server 2008 platforms; there is no need to rebuild the code when porting it across binary-compatible platforms.

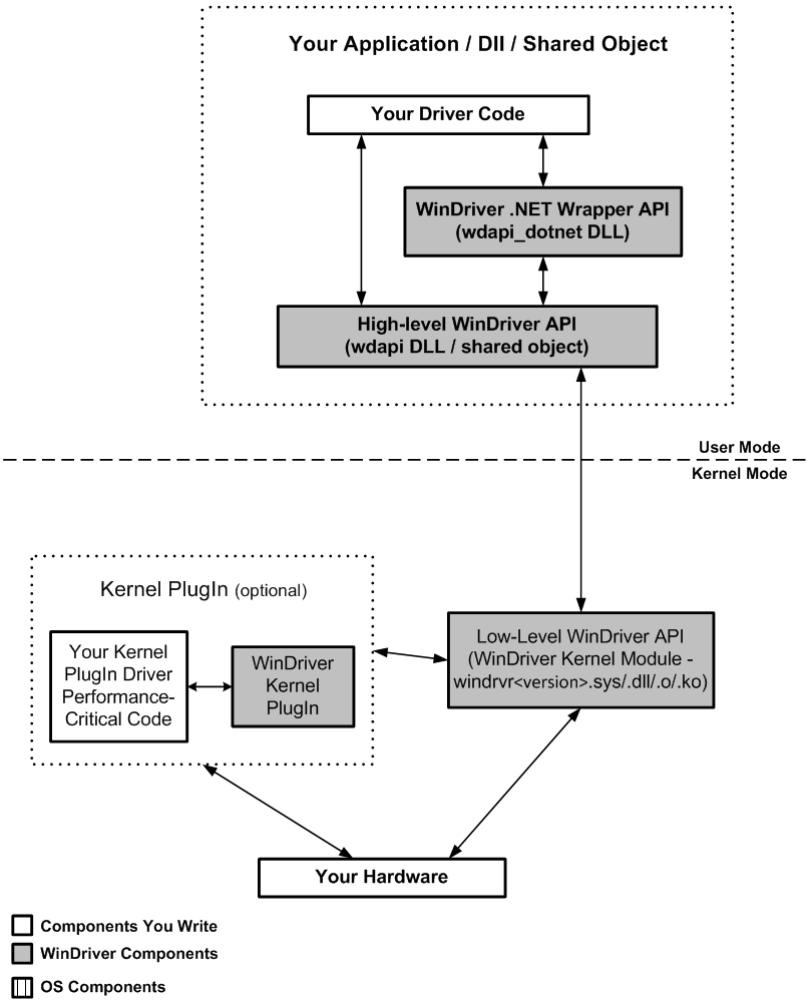
1.5. WinDriver Benefits

- Easy user-mode driver development.
- Kernel PlugIn for high-performance drivers.
- Friendly DriverWizard allows hardware diagnostics without writing a single line of code.
- Automatically generates the driver code for the project in C or C#.
- Supports any PCI/ISA/EISA/CompactPCI/PCI Express device, regardless of manufacturer.

- Enhanced support for specific chipsets [7] frees the developer of the need to study the hardware's specification.
- Applications are binary compatible across Windows 10/Server 2016/8.1/Server 2012 R2/8/Server 2012/7/Server 2008 R2/Server 2008.
- Applications are source code compatible across all supported operating systems — Windows 10/Server 2016/8.1/Server 2012 R2/8/Server 2012/7/Server 2008 R2/Server 2008, Windows 10 IoT/Embedded Windows 8.1/8/7, and Linux.
- Can be used with common development environments, including MS Visual Studio, C++, GCC, Windows GCC, or any other appropriate compiler/environment.
- No WDK, ETK, DDI or any system-level programming knowledge required.
- Supports I/O, DMA, interrupt handling and access to memory-mapped cards.
- Supports multiple CPUs and multiple PCI bus platforms (PCI/ISA/EISA/CompactPCI/PCI Express).
- Supports 64-bit PCI data transfers.
- Includes dynamic driver loader.
- Comprehensive documentation and help files.
- Detailed examples in C or C#.
- WinDriver Windows drivers are compliant with Microsoft's Windows Certification Program
- Two months of free technical support.
- No run-time fees or royalties.

1.6. WinDriver Architecture

Figure 1.1. WinDriver Architecture



For hardware access, your application calls one of the WinDriver user-mode functions. The user-mode function calls the WinDriver kernel, which accesses the hardware for you through the native calls of the operating system.

WinDriver's design minimizes performance hits on your code, even though it is running in user mode. However, some hardware drivers have high performance requirements that cannot be achieved in user mode. This is where WinDriver's edge sharpens. After easily creating and debugging your code in user mode, you may drop the performance-critical modules of your code (such as a hardware interrupt handler) into the WinDriver Kernel PlugIn without changing them at all. Now, the WinDriver kernel calls this module from kernel mode, thereby achieving maximal performance. This allows you to program and debug in user mode, and still achieve kernel performance where needed. For a detailed overview of the Kernel PlugIn feature, see Chapter 11.

1.7. What Platforms Does WinDriver Support?

WinDriver supports the following operating systems:

- Windows 10/Server 2016/8.1/Server 2012 R2/8/Server 2012/7/Server 2008 R2/Server 2008 and Windows 10 IoT/Embedded Windows 8.1/8/7 — henceforth collectively: **Windows**
- Linux

The same source code will run on all supported platforms — simply recompile it for the target platform. The source code is binary compatible across Windows 10/Server 2016/8.1/Server 2012 R2/8/Server 2012/7/Server 2008 R2/Server 2008; WinDriver executables can be ported among the binary-compatible platforms without recompilation.

Even if your code is meant only for one of the supported operating systems, using WinDriver will give you the flexibility to move your driver to another operating system in the future without needing to change your code.

OS-specific support is provided only for operating systems with official vendor support.

1.8. Limitations of the Different Evaluation Versions

All the evaluation versions of WinDriver are full featured. No functions are limited or crippled in any way. The evaluation version of WinDriver varies from the registered version in the following ways:

- Each time WinDriver is activated, an *Unregistered* message appears.
- When using DriverWizard, a dialogue box with a message stating that an evaluation version is being run appears on every interaction with the hardware.
- In the Linux the driver will remain operational for 60 minutes, after which time it must be restarted.
- The Windows evaluation version expires 30 days from the date of installation.

For more details please refer to Appendix E.

1.9. How Do I Develop My Driver with WinDriver?

1.9.1. On Windows and Linux

1. Start DriverWizard and use it to diagnose your hardware — see details in Chapter 4.
2. Let DriverWizard generate skeletal code for your driver, or use one of the WinDriver samples as the basis for your driver application (see Chapter 7 for details regarding WinDriver's enhanced support for specific chipsets).
3. Modify the generated/sample code to suit your application's needs.
4. Run and debug your driver in the user mode.
5. If your code contains performance-critical sections, refer to Chapter 10 for suggestions on how to improve your driver's performance.

The code generated by DriverWizard is a diagnostics program that contains functions that read and write to any resource detected or defined (including custom-defined registers), enables your card's interrupts, listens to them, and more.

1.10. What Does the WinDriver Toolkit Include?

- Two months of basic technical support (via support center)
- WinDriver modules
- Utilities
- Samples and wrapper APIs for enhanced-support chipsets

1.10.1. WinDriver Modules

- WinDriver (**WinDriver/include**) — the general purpose hardware access toolkit. The main files here are
  - **windrvr.h**: Declarations and definitions of WinDriver's basic API.
  - **wdc_lib.h** and **wdc_defs.h**: Declarations and definitions of the WinDriver Card (WDC) library, which provides convenient wrapper APIs for accessing PCI/ISA/EISA/CompactPCI/PCI Express devices (see Section B.2).

  - **windrvr_int_thread.h**: Declarations of convenient wrapper functions to simplify interrupt handling.
  - **windrvr_events.h**: Declarations of APIs for handling Plug-and-Play and power management events.
  - **utils.h**: Declarations of general utility functions.
  - **status_strings.h**: Declarations of API for converting WinDriver status codes to descriptive error strings.

- DriverWizard (**WinDriver/wizard/wdwizard**) — a graphical application that diagnoses your hardware and enables you to easily generate code for your driver (refer to Chapter 4 for details).
- Debug Monitor — a debugging tool that collects information about your driver as it runs. This tool is available both as a fully graphical application — **WinDriver/util/wddebug_gui** — and as a console-mode application — **WinDriver/util/wddebug**.
  For details regarding the Debug Monitor, refer to Section 6.2.
- WinDriver distribution package (**WinDriver/redist**) — the files you include in the driver distribution to customers.
- WinDriver Kernel PlugIn — the files and samples needed to create a kernel-mode Kernel PlugIn driver (refer to Chapter 11 for details.)
- This manual — the full WinDriver manual (this document), in different formats, can be found under the **WinDriver/docs** directory.

1.10.2. Utilities

- **pci_dump.exe** (**WinDriver/util/pci_dump.exe**) — used to obtain a dump of the PCI configuration registers of the installed PCI cards.
- **pci_diag.exe** (**WinDriver/util/pci_diag.exe**) — used for reading/writing PCI configuration registers, accessing PCI I/O and memory ranges and handling PCI interrupts.
- **pci_scan.exe** (**WinDriver/util/pci_scan.exe**) — used to obtain a list of the PCI cards installed and the resources allocated for each card.

1.10.3. Samples and Enhanced-Support Chipset APIs

WinDriver includes a variety of samples that demonstrate how to use WinDriver's API to communicate with your device and perform various driver tasks.

- C samples: found under the **WinDriver/samples** directory.
  These samples also include the source code for the utilities listed above [1.10.2].
- Python samples: found under the **WinDriver/samples/python** directory.
  These samples also include the source code for the utilities listed above [1.10.2].
- .NET C# samples (Windows): found under the **WinDriver\csharp.net** directory.

1.10.3.1. Enhanced Chipset Support

In addition to the generic samples described above, WinDriver provides custom wrapper APIs and sample code for major PCI chipsets, as outlined in Chapter 7. The relevant files are provided in the following WinDriver installation directories:

- PLX 6466, 9030, 9050, 9052, 9054, 9056, 9080 and 9656 — **WinDriver/plx**
- Altera Qsys design — **WinDriver/altera/qsys_design**
- Xilinx Bus Master DMA (BMD) design — **WinDriver/xilinx/bmd_design**
- Xilinx XDMA design — **WinDriver/xilinx/XDMA_design**

For the Xilinx BMD, Xilinx XDMA and Altera Qsys designs there is also an option to generate customized driver code that utilizes the related enhanced-support APIs.

1.11. Can I Distribute the Driver Created with WinDriver?

Yes. WinDriver is purchased as a development toolkit, and any device driver created using WinDriver may be distributed, royalties free, in as many copies as you wish. See the license agreement at (**WinDriver/docs/wd_license.pdf**) for more details.

Chapter 2
Understanding Device Drivers

This chapter provides you with a general introduction to device drivers and takes you through the structural elements of a device driver.

Using WinDriver, you do not need to familiarize yourself with the internal workings of driver development. As explained in Chapter 1 of the manual, WinDriver enables you to communicate with your hardware and develop a driver for your device from the user mode, using only WinDriver's simple APIs, without any need for driver or kernel development knowledge.

2.1. Device Driver Overview

Device drivers are the software segments that provides an interface between the operating system and the specific hardware devices — such as terminals, disks, tape drives, video cards, and network media. The device driver brings the device into and out of service, sets hardware parameters in the device, transmits data from the kernel to the device, receives data from the device and passes it back to the kernel, and handles device errors.

A driver acts like a translator between the device and programs that use the device. Each device has its own set of specialized commands that only its driver knows. In contrast, most programs access devices by using generic commands. The driver, therefore, accepts generic commands from a program and then translates them into specialized commands for the device.

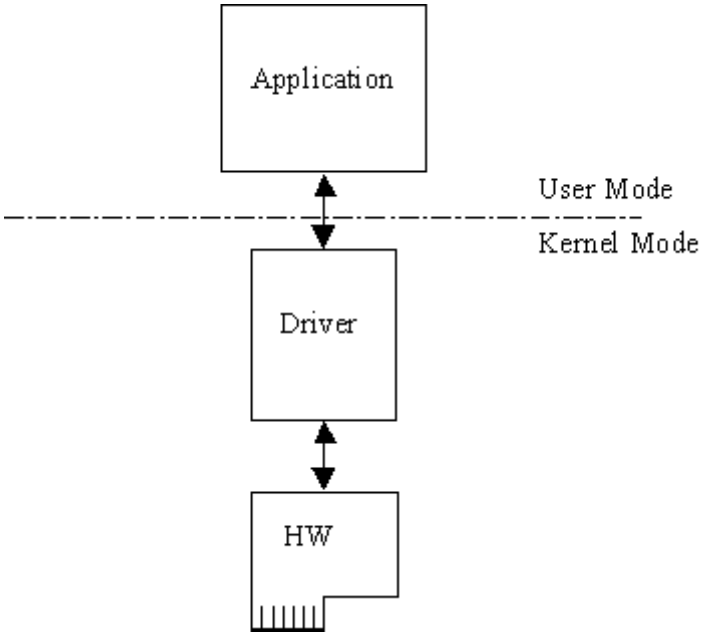
2.2. Classification of Drivers According to Functionality

There are numerous driver types, differing in their functionality. This subsection briefly describes three of the most common driver types.

2.2.1. Monolithic Drivers

Monolithic drivers are device drivers that embody all the functionality needed to support a hardware device. A monolithic driver is accessed by one or more user applications, and directly drives a hardware device. The driver communicates with the application through I/O control commands (IOCTLs) and drives the hardware using calls to the different WDK, ETK, DDI/DKI functions.

Figure 2.1. Monolithic Drivers



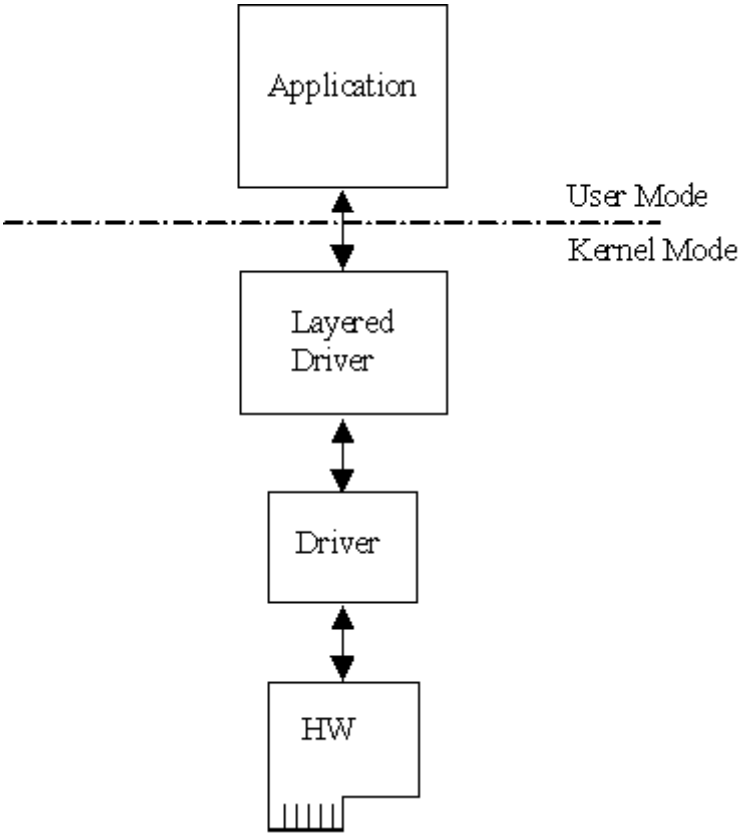
Monolithic drivers are supported in all operating systems including all Windows platforms and all Unix platforms.

2.2.2. Layered Drivers

Layered drivers are device drivers that are part of a stack of device drivers that together process an I/O request. An example of a layered driver is a driver that intercepts calls to the disk and encrypts/decrypts all data being transferred to/from the disk. In this example, a driver would be hooked on to the top of the existing driver and would only do the encryption/decryption.

Layered drivers are sometimes also known as filter drivers, and are supported in all operating systems including all Windows platforms and all Unix platforms.

Figure 2.2. Layered Drivers

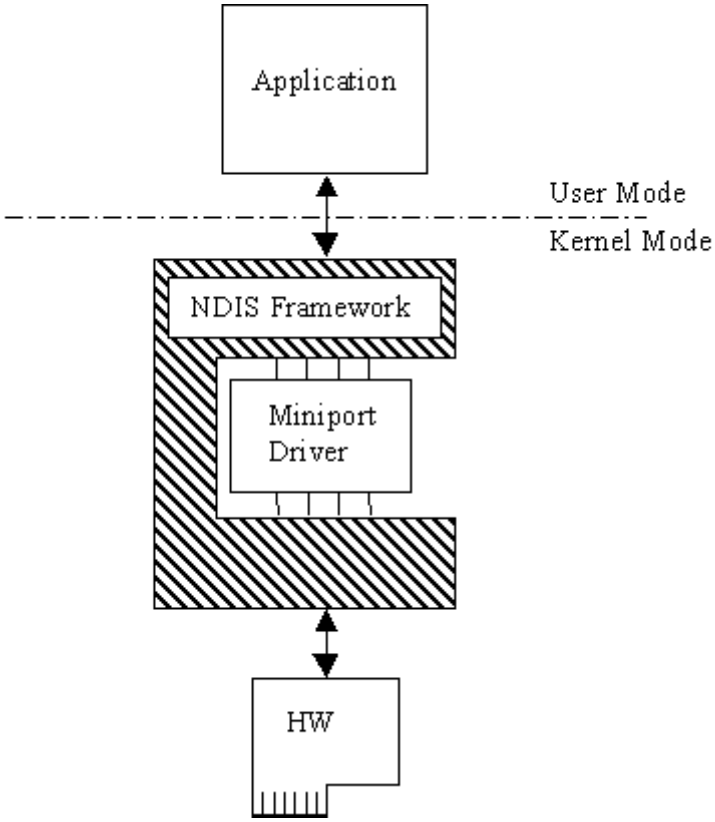


2.2.3. Miniport Drivers

A Miniport driver is an add-on to a class driver that supports miniport drivers. It is used so the miniport driver does not have to implement all of the functions required of a driver for that class. The class driver provides the basic class functionality for the miniport driver.
A class driver is a driver that supports a group of devices of common functionality, such as all HID devices or all network devices.

Miniport drivers are also called miniclass drivers or minidrivers, and are supported in the Windows 7 and higher operating systems.

Figure 2.3. Miniport Drivers



The Windows 7 and higher operating systems provide several driver classes (called ports) that handle the common functionality of their class. It is then up to the user to add only the functionality that has to do with the inner workings of the specific hardware. The NDIS miniport driver is one example of such a driver. The NDIS miniport framework is used to create network drivers that hook up to Windows's communication stacks, and are therefore accessible to common communication calls used by applications. The Windows kernel provides drivers for the various communication stacks and other code that is common to communication cards. Due to the NDIS framework, the network card developer does not have to write all of this code, only the code that is specific to the network card he is developing.

2.3. Classification of Drivers According to Operating Systems

2.3.1. WDM Drivers

Windows Driver Model (WDM) drivers are kernel-mode drivers within the Windows operating systems. WDM works by channeling some of the work of the device driver into portions of the code that are integrated into the operating system. These portions of code handle all of the low-level buffer management, including DMA and Plug-and-Play (Pnp) device enumeration. WDM drivers are PnP drivers that support power management protocols, and include monolithic drivers, layered drivers and miniport drivers.

2.3.2. Unix Device Drivers

In the classic Unix driver model, devices belong to one of three categories: character (char) devices, block devices and network devices. Drivers that implement these devices are correspondingly known as char drivers, block drivers or network drivers. Under Unix, drivers are code units linked into the kernel that run in privileged kernel mode. Generally, driver code runs on behalf of a user-mode application. Access to Unix drivers from user-mode applications is provided via the file system. In other words, devices appear to the applications as special device files that can be opened.

Unix device drivers are either layered or monolithic drivers. A monolithic driver can be perceived as a one-layer layered driver.

2.3.3. Linux Device Drivers

Linux device drivers are based on the classic Unix device driver model [2.3.2]. In addition, Linux introduces some new characteristics.

Under Linux, a block device can be accessed like a character device, as in Unix, but also has a block-oriented interface that is invisible to the user or application.

Traditionally, under Unix, device drivers are linked with the kernel, and the system is brought down and restarted after installing a new driver. Linux introduces the concept of a dynamically loadable driver called a module. Linux modules can be loaded or removed dynamically without requiring the system to be shut down. A Linux driver can be written so that it is statically linked or written in a modular form that allows it to be dynamically loaded. This makes Linux memory usage very efficient because modules can be written to probe for their own hardware and unload themselves if they cannot find the hardware they are looking for.

Like Unix device drivers, Linux device drivers are either layered or monolithic drivers.

2.4. The Entry Point of the Driver

Every device driver must have one main entry point, like the `main`() function in a C console application. This entry point is called `DriverEntry`() in Windows and `init_module`() in Linux. When the operating system loads the device driver, this driver entry procedure is called.

There is some global initialization that every driver needs to perform only once when it is loaded for the first time. This global initialization is the responsibility of the `DriverEntry`()/`init_module`() routine. The entry function also registers which driver callbacks will be called by the operating system. These driver callbacks are operating system requests for services from the driver. In Windows, these callbacks are called *dispatch routines*, and in Linux they are called *file operations*. Each registered callback is called by the operating system as a result of some criteria, such as disconnection of hardware, for example.

2.5. Associating the Hardware with the Driver

Operating systems differ in the ways they associate a device with a specific driver.

In Windows, the hardware-driver association is performed via an INF file, which registers the device to work with the driver. This association is performed before the `DriverEntry`() routine is called. The operating system recognizes the device, checks its database to identify which INF file is associated with the device, and according to the INF file, calls the driver's entry point.

In Linux, the hardware-driver association is defined in the driver's `init_module`() routine. This routine includes a callback that indicates which hardware the driver is designated to handle. The operating system calls the driver's entry point, based on the definition in the code.

2.6. Communicating with Drivers

Communication between a user-mode application and the driver that drives the hardware, is implemented differently for each operating system, using the custom OS Application Programming Interfaces (APIs).

On Windows, and Linux, the application can use the OS file-access API to open a handle to the driver (e.g., using the Windows `CreateFile`() function or using the Linux `open`() function), and then read and write from/to the device by passing the handle to the relevant OS file-access functions (e.g., the Windows `ReadFile`() and `WriteFile`() functions, or the Linux `read`() and `write`() functions).

The application sends requests to the driver via I/O control (IOCTL) calls, using the custom OS APIs provided for this purpose (e.g., the Windows `DeviceIoControl`() function, or the Linux `ioctl`() function).
The data passed between the driver and the application via the IOCTL calls is encapsulated using custom OS mechanisms. For example, on Windows the data is passed via an I/O Request Packet (IRP) structure, and is encapsulated by the I/O Manager.

Chapter 3
Installing WinDriver

This chapter takes you through the process of installing WinDriver on your development platform, and shows you how to verify that your WinDriver is properly installed. The last section discusses the uninstall procedure. To find out how to install the driver you create on target platforms, refer to Chapter 14.

3.1. System Requirements

3.1.1. Windows System Requirements

- Any x86 32-bit or 64-bit (x64: AMD64 or Intel EM64T) processor
- Any compiler or development environment supporting C or .NET

3.1.2. Windows 10 IoT Core System Requirements

WinDriver supports driver development for the Windows 10 IoT Core operating system. Please note that Windows 10 IoT Enterprise is a full version of Windows 10, so the regular WinDriver for Windows desktop / server can be used for those OSes.

- WinDriver must be installed on a development computer running a desktop version of Windows, in order to use DriverWizard.
- A network connection allowing an SSH session with the target computer.

3.1.3. Linux System Requirements

- Any of the following processor architectures, with a 2.6.x or higher Linux kernel:
  - 32-bit x86
  - 64-bit x86 AMD64 or Intel EM64T (**x86_64**)

Jungo strives to support new Linux kernel versions as close as possible to their release. To find out the latest supported kernel version, refer to the WinDriver release notes (found online at https://www.jungo.com/st/support/windriver/wdver/).

- A GCC compiler

The version of the GCC compiler should match the compiler version used for building the running Linux kernel.

- Any 32-bit or 64-bit development environment (depending on your target configuration) supporting C for user mode
- On your development PC: **glibc2.14.x (or newer)**
- The following libraries are required for running GUI WinDriver application (e.g., DriverWizard [4]; Debug Monitor [6.2]):
  - libstdc++.so.6
  - libpng12.so.0
  - libQtGui.so.4
  - libQtCore.so.4
  - libQtNetwork.so.4

3.2. WinDriver Installation Process

3.2.1. Windows WinDriver Installation Instructions

Driver installation on Windows requires administrator privileges.

1. Run the WinDriver installation — **WD1281.EXE** — and follow the installation instructions.
2. At the end of the installation, you may be prompted to reboot your computer.

- The WinDriver installation defines a **WD_BASEDIR** environment variable, which is set to point to the location of your WinDriver directory, as selected during the installation. This variable is used during the DriverWizard [4] code generation — it determines the default directory for saving your generated code and is used in the include paths of the generated project/make files. This variable is also used in the sample Kernel PlugIn projects and makefiles.

- If the installation fails with an **ERROR_FILE_NOT_FOUND** error, inspect the Windows registry to see if the **RunOnce** key exists in **HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\Windows\CurrentVersion**. This registry key is required by Windows Plug-and-Play in order to properly install drivers using INF files. If the **RunOnce** key is missing, create it; then try installing the INF file again.

The following steps are for registered users only:

To register your copy of WinDriver with the license you received from Jungo, follow these steps:

3. Start DriverWizard: **Start | Programs | WinDriver | DriverWizard**.

4. Select the **Register WinDriver** option from the **File** menu, and insert the license string you received from Jungo.

5. Click the **Activate License** button.

6. To register source code that you developed during the evaluation period, refer to the documentation of `WDC_DriverOpen()` [B.3.2]. When using the low-level `WD_xxx` API instead of the `WDC_xxx` API [B.2] (which is used by default), refer to the documentation of `WD_License()` in the **WinDriver PCI Low-Level API Reference**.

3.2.2. Linux WinDriver Installation Instructions

3.2.2.1. Preparing the System for Installation

In Linux, kernel modules must be compiled with the same header files that the kernel itself was compiled with. Since WinDriver installs kernel modules, it must compile with the header files of the Linux kernel during the installation process.

Therefore, before you install WinDriver for Linux, verify that the Linux source code and the file **version.h** are installed on your machine:

Install the Linux kernel source code:

- If you have yet to install Linux, install it, including the kernel source code, by following the instructions for your Linux distribution.

- If Linux is already installed on your machine, check whether the Linux source code was installed. You can do this by looking for 'linux' in the **/usr/src** directory. If the source code is not installed, either install it, or reinstall Linux with the source code, by following the instructions for your Linux distribution.

Install version.h:

- The file **version.h** is created when you first compile the Linux kernel source code. Some distributions provide a compiled kernel without the file **version.h**. Look under **/usr/src/linux/include/linux** to see whether you have this file. If you do not, follow these steps:

  1. Become super user:
     `$ su`

  2. Change directory to the Linux source directory:
     `# cd /usr/src/linux`

  3. Type:
     `# make xconfig`

  4. Save the configuration by choosing **Save and Exit**.

  5. Type:
     `# make dep`

  6. Exit super user mode:
     `# exit`

To run GUI WinDriver applications (e.g., DriverWizard [4]; Debug Monitor [6.2]) you must also have version 6.0 of the **libstdc++** library — **libstdc++.so.6** — and version 12.0 of the **libpng** library — **libpng12.so.0**. If you do not have these files, install the relevant packages for your Linux distribution (e.g., **libstdc++6** and **libpng12-0**). Also required is the **libqtgui4** package.

Before proceeding with the installation, you must also make sure that you have a *linux* symbolic link. If you do not, create one by typing
`/usr/src$ ln -s <target kernel> linux`
For example, for the Linux 3.0 kernel type
`/usr/src$ ln -s linux-3.0/ linux`

3.2.2.2. Installation

1. On your development Linux machine, change directory to your preferred installation directory, for example to your home directory:
   `$ cd ~`

   
   The path to the installation directory must not contain any spaces.

2. Extract the WinDriver distribution file — **WD1281LN.tgz** or **WD1281LNx86_64.tgz** —
   `$ tar xvzf <file location>/WD1281LN[x86_64].tgz`

   For example, to extract **WD1281LN.tgz** run this command:
   `$ tar xvzf ~/WD1281LN.tgz`

3. Change directory to your WinDriver **redist** directory (the tar automatically creates a **WinDriver** directory):
   `$ cd <WinDriver directory path>/redist`

4. Install WinDriver:

   a. **`<WinDriver directory>/redist$ ./configure --disable-usb-support`**

   - The configuration script creates a makefile based on the running kernel. You may select to use another installed kernel source, by executing the script with the **`--with-kernel-source=<path>`** option, where **`<path>`** is the full path to the kernel source directory — e.g., **/usr/src/linux**.
   - If the Linux kernel version is 2.6.26 or higher, the configuration script generates makefiles that use **kbuild** to compile the kernel modules. You can force the use of **kbuild** on earlier versions of Linux, by executing the configuration script with the **`--enable-kbuild`** flag.

   For a full list of the configuration script options, use the **`--help`** option:
   `./configure --help`

   b. **`<WinDriver directory>/redist$ make`**

   c. Become super user:
   `<WinDriver directory>/redist$ su`

   d. Install the driver:
   `<WinDriver directory>/redist# make install`

5. Create a symbolic link so that you can easily launch the DriverWizard GUI:
   `$ ln -s <path to WinDriver>/wizard/wdwizard /usr/bin/wdwizard`

6. Change the read and execute permissions on the file **wdwizard** so that ordinary users can access this program.

7. Change the user and group IDs and give read/write permissions to the device file **/dev/windrvr1281**, depending on how you wish to allow users to access hardware through the device. Due to security reasons, by default the device file is created with permissions only for the root user. Change the permissions by modifying your **/etc/udev/permissions.d/50-udev.permissions** file. For example, add the following line to provide read and write permissions:
   `windrvr1281:root:root:0666`

8. Define a new **WD_BASEDIR** environment variable and set it to point to the location of your WinDriver directory, as selected during the installation. This variable is used in the make and source files of the WinDriver samples and generated DriverWizard [4] code, and is also used to determine the default directory for saving your generated DriverWizard projects. If you do not define this variable you will be instructed to do so when attempting to build the sample/ generated code using the WinDriver makefiles.

9. Exit super user mode:
   ```
   # exit
   ```

10. You can now start using WinDriver to access your hardware and generate your driver code!

Use the **WinDriver/util/wdreg** script to load the WinDriver kernel module [13.5].

The following steps are for registered users only:

To register your copy of WinDriver with the license you received from Jungo, follow these steps:

12. Start DriverWizard:
    ```
    $ <path to WinDriver>/wizard/wdwizard
    ```

13. Select the **Register WinDriver** option from the **File** menu, and insert the license string you received from Jungo.

14. Click the **Activate License** button.

15. To register source code that you developed during the evaluation period, refer to the documentation of `WDC_DriverOpen()` [B.3.2]. When using the low-level `WD_xxx` API instead of the `WDC_xxx` API [B.2] (which is used by default), refer to the documentation of `WD_License()` in the **WinDriver PCI Low-Level API Reference**.

3.2.2.3. Restricting Hardware Access on Linux

Since **/dev/windrvr1281** gives direct hardware access to user programs, it may compromise kernel stability on multi-user Linux systems. Please restrict access to DriverWizard and the device file **/dev/windrvr1281** to trusted users.

For security reasons the WinDriver installation script does not automatically perform the steps of changing the permissions on **/dev/windrvr1281** and the DriverWizard application (**wdwizard**).

3.3. Upgrading Your Installation

To upgrade to a new version of WinDriver, follow the installation steps for your target operating system, as outlined in the previous section [3.2]. You can either choose to overwrite the existing installation or install to a separate directory.

After the installation, start DriverWizard and enter the new license string, if you have received one. This completes the minimal upgrade steps.

To upgrade your source code —

- Pass the new license string as a parameter to `WDC_DriverOpen()` [B.3.2] (or to `WD_License()` — see the **WinDriver PCI Low-Level API Reference** — when using the low-level `WD_xxx` API instead of the `WDC_xxx` API [B.2].

- Verify that the call to `WD_DriverName()` [B.1] in your driver code (if exists) uses the name of the new driver module — **windrvr1281** or your renamed version of this driver [15.2].
  If you use the generated DriverWizard code or one of the samples from the new WinDriver version, the code will already use the default driver name from the new version. Also, if your code is based on generated/sample code from an earlier version of WinDriver, rebuilding the code with **windrvr.h** from the new version is sufficient to update the code to use the new default driver-module name (due to the use of the `WD_DEFAULT_DRIVER_NAME_BASE` definition).
  If you elect to rename the WinDriver driver module [15.2], ensure that your code calls `WD_DriverName()` [B.1] with your custom driver name. If you rename the driver from the new version to a name already used in your old project, you do not need to modify your code.

3.4. Checking Your Installation

3.4.1. Windows and Linux Installation Check

1. Start DriverWizard — **<path to WinDriver>/wizard/wdwizard**. On Windows you can also run DriverWizard from the **Start** menu: **Start | Programs | WinDriver | DriverWizard**.

2. If you are a registered user, make sure that your WinDriver license is registered (refer to Section 3.2, which explains how to install WinDriver and register your license).
   If you are an evaluation version user, you do not need to register a license.

3. For PCI cards — Insert your card into the PCI bus, and verify that DriverWizard detects it.

4. For ISA cards (Windows and Linux) — Insert your card into the ISA bus, configure DriverWizard with your card's resources and try to read/write to the card using DriverWizard.

3.5. Uninstalling WinDriver

This section will help you to uninstall either the evaluation or registered version of WinDriver.

3.5.1. Windows WinDriver Uninstall Instructions

- You can select to use the graphical **wdreg_gui.exe** utility instead of **wdreg.exe**.
- **wdreg.exe** and **wdreg_gui.exe** are found in the **WinDriver\util** directory (see Chapter 13 for details regarding these utilities).

1. Close any open WinDriver applications, including DriverWizard, the Debug Monitor, and user-specific applications.

2. If you created a Kernel PlugIn driver [11], uninstall and erase it:

   a. If your Kernel PlugIn driver is currently installed, uninstall it using the **wdreg** utility:
   ```
   wdreg -name <Kernel PlugIn name> uninstall
   ```

   The Kernel PlugIn driver name should be specified without the *.sys extension.

   b. Erase your Kernel PlugIn driver from the **%windir%\system32\drivers** directory.

3. Uninstall all Plug-and-Play devices (USB/PCI) that have been registered with WinDriver via an INF file:

   - Uninstall the device using the **wdreg** utility:
   ```
   wdreg -inf <path to the INF file> uninstall
   ```

   - Verify that no INF files that register your device(s) with WinDriver's kernel module (**windrvr1281.sys**) are found in the **%windir%\inf** directory.

4. Uninstall WinDriver:

   - **On the development PC**, on which you installed the WinDriver toolkit:
     Run **Start | WinDriver | Uninstall** , **OR** run the **uninstall.exe** utility from the **WinDriver** installation directory.

     The uninstall will stop and unload the WinDriver kernel module (**windrvr1281.sys**); delete the copy of the **windrvr1281.inf** file from the **%windir%\inf** directory; delete WinDriver from Windows' **Start** menu; delete the **WinDriver** installation directory (except for files that you added to this directory); and delete the shortcut icons to the DriverWizard and Debug Monitor utilities from the Desktop.

   - **On a target PC**, on which you installed the WinDriver kernel module (**windrvr1281.sys**), but not the entire WinDriver toolkit:
     Use the **wdreg** utility to stop and unload the driver:
     ```
     wdreg -inf <path to windrvr1281.inf> uninstall
     ```

     When running this command, **windrvr1281.sys** should reside in the same directory as **windrvr1281.inf**.

(On the development PC, the relevant **wdreg** uninstall command is executed for you by the uninstall utility).

- If you attempt to uninstall WinDriver while there are open handles to the WinDriver service (**windrvr1281.sys** or your renamed driver [15.2], or there are connected and enabled Plug-and-Play devices that are registered to work with this service, **wdreg** will fail to uninstall the driver. This ensures that you do not uninstall the driver while it is being used.

- You can check if the WinDriver kernel module is loaded by running the Debug Monitor utility (**WinDriver\util\wddebug_gui.exe**) [6.2]. When the driver is loaded, the Debug Monitor log displays driver and OS information; otherwise, it displays a relevant error message. On the development PC, the uninstall command will delete the Debug Monitor executables; to use this utility after the uninstallation, create a copy of **wddebug_gui.exe** before performing the uninstall procedure.

5. If **windrvr1281.sys** was successfully unloaded, erase the following files (if they exist):

   - **%windir%\system32\drivers\windrvr1281.sys**
   - **%windir%\inf\windrvr1281.inf**
   - **%windir%\system32\wdapi1281.dll**
   - **%windir%\sysWOW64\wdapi1281.dll** (Windows x64)

6. Reboot the computer.

3.5.2. Linux WinDriver Uninstall Instructions

The following commands must be executed with root privileges.

1. Verify that the WinDriver driver module is not being used by another program:
   - View the list of modules and the programs using each of them:
     `# /sbin/lsmod`
   - Identify any applications and modules that are using the WinDriver driver module. (By default, WinDriver module names begin with **windrvr1281**).
   - Close any applications that are using the WinDriver driver module.
   - If you created a Kernel PlugIn driver [11], unload the Kernel PlugIn driver module:
     `# /sbin/rmmod kp_xxx_module`
2. Run the following command to unload the WinDriver driver module:
   `# /sbin/modprobe -r windrvr1281`
3. If you created a Kernel PlugIn driver, remove it as well.
4. Remove the file **.windriver.rc** from the **/etc** directory:
   `# rm -f /etc/.windriver.rc`
5. Remove the file **.windriver.rc** from **$HOME**:
   `# rm -f $HOME/.windriver.rc`
6. If you created a symbolic link to DriverWizard, remove the link using the command
   `# rm -f /usr/bin/wdwizard`
7. Remove the WinDriver installation directory using the command
   `# rm -rf <path to the WinDriver directory>`
   (for example: `# rm -rf ~/WinDriver`).
8. Remove the WinDriver shared object file, if it exists:
   /usr/lib/libwdapi1281.so (32-bit x86) /
   /usr/lib64/libwdapi1281.so (64-bit x86).

Chapter 4
Using DriverWizard

This chapter describes the WinDriver DriverWizard utility and its hardware diagnostics and driver code generation capabilities.

4.1. An Overview

DriverWizard (included in the WinDriver toolkit) is a graphical user interface (GUI) tool that is targeted at two major phases in the hardware and driver development:

- **Hardware diagnostics** — DriverWizard enables you to write and read hardware resources before writing a single line of code. After the hardware has been built, insert your device into the appropriate bus slot on your machine, view its resources — memory and I/O ranges, PCI configuration registers, and interrupts — and verify the hardware's functionality by reading/ writing memory and I/O addresses, defining and accessing custom registers, and listening to interrupts.

- **Code generation** — Once you have verified that the device is operating to your satisfaction, use DriverWizard generate skeletal driver source code with functions to view and access your hardware's resources.

If you are developing a driver for a device that is based on an enhanced-support PCI chipset (PLX 6466, 9030, 9050, 9052, 9054, 9056, 9080 and 9656; Altera Qsys design; Xilinx BMD design; Xilinx XDMA design), we recommend that you first read Chapter 7: *Enhanced Support for Specific Chipsets* to understand your development options.

On Windows, DriverWizard can also be used to generate an INF file [15.1] for your hardware.

The code generated by DriverWizard is composed of the following elements:

- **Library functions** for accessing each element of your device's resources (memory ranges, I/O ranges, registers and interrupts).

- **A 32-bit diagnostics program** in console mode with which you can diagnose your device. This application utilizes the special library functions described above. Use this diagnostics program as your skeletal device driver.

- **A project solution** that you can use to automatically load all of the project information and files into your development environment.
  For Linux, DriverWizard generates the required makefile.

4.2. DriverWizard Walkthrough

To use DriverWizard, follow these steps:

1. **Attach your hardware to the computer:**
   Attach the card to the appropriate bus slot on your computer.
   Alternatively, you have the option to use DriverWizard to generate code for a virtual PCI device, without having the actual device installed, by selecting the **PCI Virtual Device** DriverWizard option (see information in Step 2). When selecting this option, DriverWizard will generate code for your *virtual PCI device*.

2. **Run DriverWizard and select your device:**

   a. Start DriverWizard — **<path to WinDriver>/wizard/wdwizard**. On Windows you can also run DriverWizard from the **Start** menu: **Start | Programs | WinDriver | DriverWizard**.

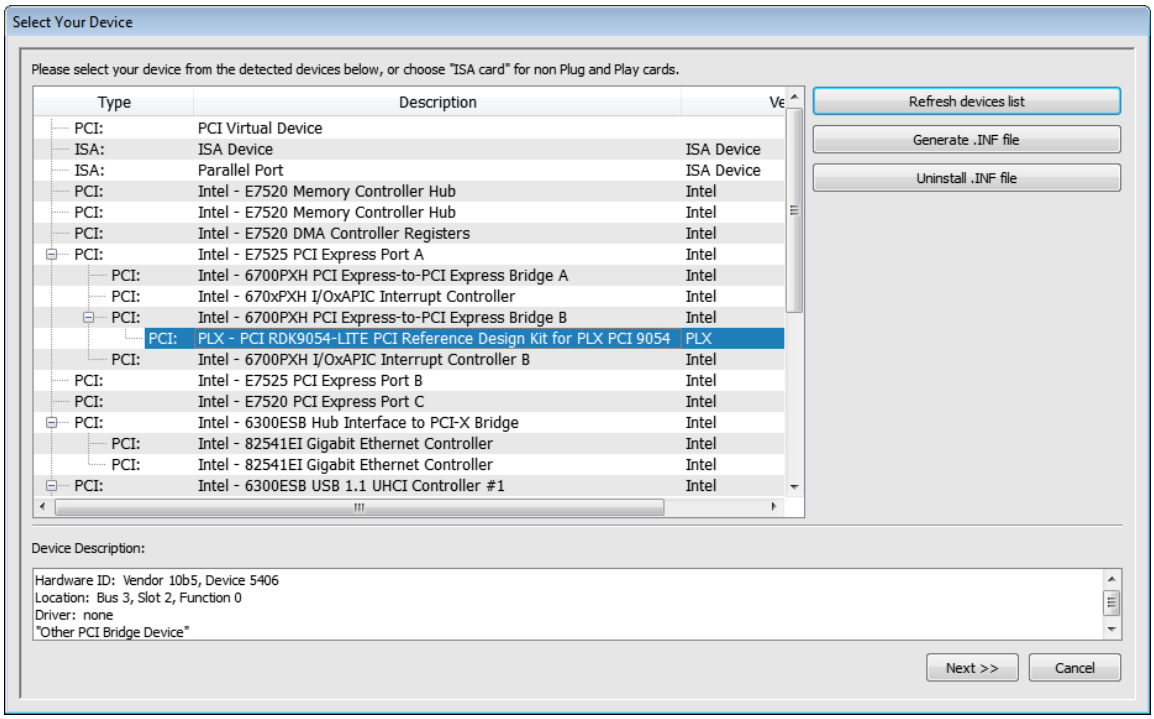
   On Windows 7 and higher you must run DriverWizard as administrator.

   b. Click **New host driver project** to start a new project, or **Open an existing project** to open a saved session.

Figure 4.1. Create or Open a Driver Project

c. Select your Plug-and-Play card from the list of devices detected by DriverWizard.

Figure 4.2. Select Your Plug-and-Play Device



For non-Plug-and-Play cards, select **ISA**.
To generate code for a PCI device that is not currently attached to the computer, select **PCI Virtual Device**.

When selecting the **PCI Virtual Device** option, DriverWizard allows you to define the device's resources. By specifying the I/O and/or memory ranges, you may further define run-time registers (the offsets are relative to BARs). In addition, the IRQ must be specified if you want to generate code that acknowledges interrupts via run-time registers. Note, that the IRQ number and the size of the I/O and memory ranges are irrelevant, since these will be automatically detected by DriverWizard when you install a physical device.

3. **Generate and install an INF file for your device [Windows]**:
On the supported **Windows** operating systems, the driver for Plug-and-Play devices (such as PCI) is installed by installing an INF file for the device. DriverWizard enables you to generate an INF file that registers your device to work with WinDriver (i.e., with the **windrvr1281.sys** driver). The INF file generated by DriverWizard should later be distributed to your Windows customers, and installed on their PCs.
The INF file that you generate in this step is also designed to enable DriverWizard to diagnose your device on Windows (for example, when no driver is installed for your PCI device). Additional information concerning the need for an INF file is provided in Section 15.1.1.

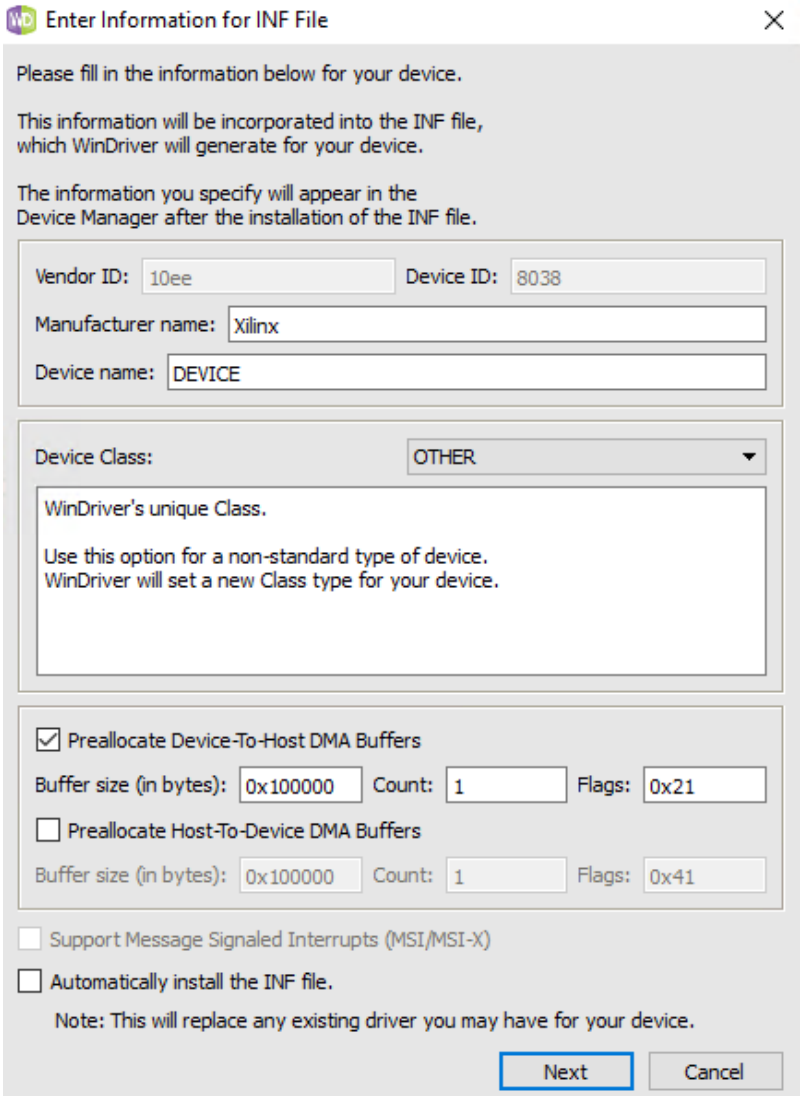
If you don't need to generate and install an INF file (e.g., if you are using DriverWizard on Linux), skip this step.

To generate and install the INF file with DriverWizard, do the following:

a. In the **Select Your Device** screen (see Step 2), click the **Generate .INF file** button or click **Next**.

b. DriverWizard will display information detected for your device — Vendor ID, Device ID, Device Class, manufacturer name and device name — and allow you to modify this information, as demonstrated in Figure 4.3 below.

Figure 4.3. DriverWizard INF File Information



c. When you are done, click **Next** and choose the directory in which you wish to store the generated INF file. DriverWizard will then automatically generate the INF file for you.

You can choose to automatically install the INF file by checking the **Automatically Install the INF file** option in the DriverWizard's INF generation dialogue.

If the automatic INF file installation fails, DriverWizard will notify you and provide manual installation instructions (refer also the manual INF file installation instructions in Section 15.1).

For further information on Preallocating DMA Buffers in Windows, please refer to Section 9.1.2.1 of the manual.

Handling of PCI Message-Signaled Interrupts (MSI) and Extended Message-Signaled Interrupts (MSI-X) requires specific configuration in the device's INF file, as explained in Section 9.2.7.1 of the manual.
On Windows 7 and higher, if your hardware supports MSI or MSI-X, the **Support Message Signaled Interrupts** option in the DriverWizard's INF generation dialogue will be enabled and checked by default. When this option is checked, the generated DriverWizard INF file for your device will include support for MSI/MSI-X handling. However, when this option is not checked, PCI interrupts will be handled using the legacy level-sensitive interrupts method, regardless of whether the hardware and OS support MSI/MSI-X.

d. When the INF file installation completes, select and open your device from the list in the **Select Your Device** screen.

4. **Uninstall the INF file of your device [Windows]:**
On Windows, you can use DriverWizard to uninstall a previously installed Plug-and-Play PCI) device INF file. This will unregister the device from its current driver and delete the copy of the INF file in the Windows INF directory.

In order for WinDriver to correctly identify the resouces of a Plug-and-Play device and communicate with it — including for the purpose of the DriverWizard device diagnostics outlined in the next step — the deivce must be registered to work with WinDriver via an INF file (see Step 3).

If you do not wish to uninstall an INF file, skip this step.

To uninstall the INF file, do the following:

a. In the **Select Your Device** screen (see Step 2), click the **Uninstall .INF file** button.

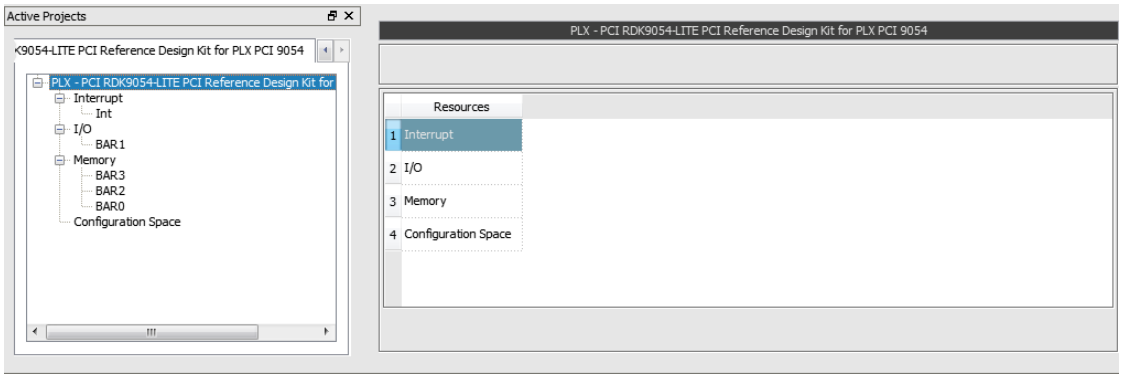
b. Select the INF file to be removed.

5. **Diagnose your device:**
Before writing your device driver, it is important to make sure your hardware is working as expected. Use DriverWizard to diagnose your hardware. All of your activity will be logged in the DriverWizard log so that you may later analyze your tests:

a. Define and test your device's I/O and memory ranges, registers and interrupts:

- DriverWizard will automatically detect your Plug-and-Play hardware resources: I/O ranges, memory ranges, and interrupts.

Figure 4.4. PCI Resources

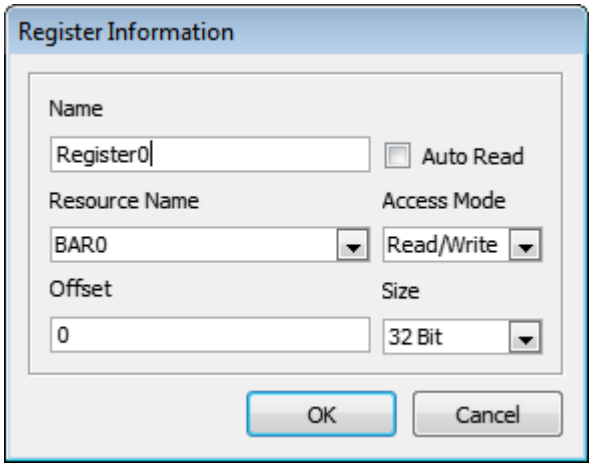


For non-Plug-and-Play hardware, define your hardware's resources manually.

On Windows 7 and higher, you may need to register an IRQ with WinDriver before you can assign it to your non-Plug-and-Play hardware [9.2.3].

You can also manually define hardware registers, as demonstrated in Figure 4.5 below.

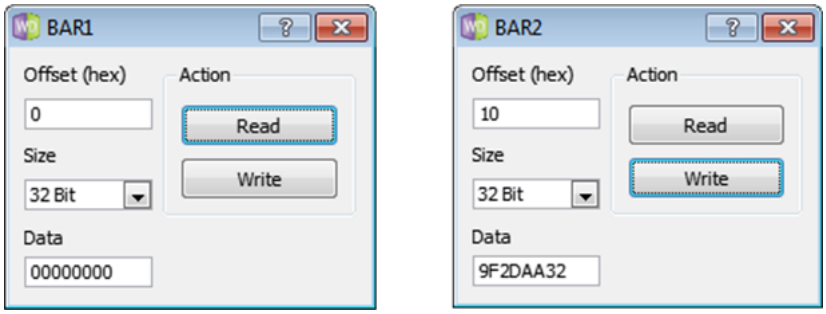
Figure 4.5. Define Registers



When defining registers, you may check the **Auto Read** box in the **Register Information** window. Registers marked as **Auto Read** will automatically be read for any register read/write operation performed from DriverWizard. The read results will be displayed in the wizard's Log window.

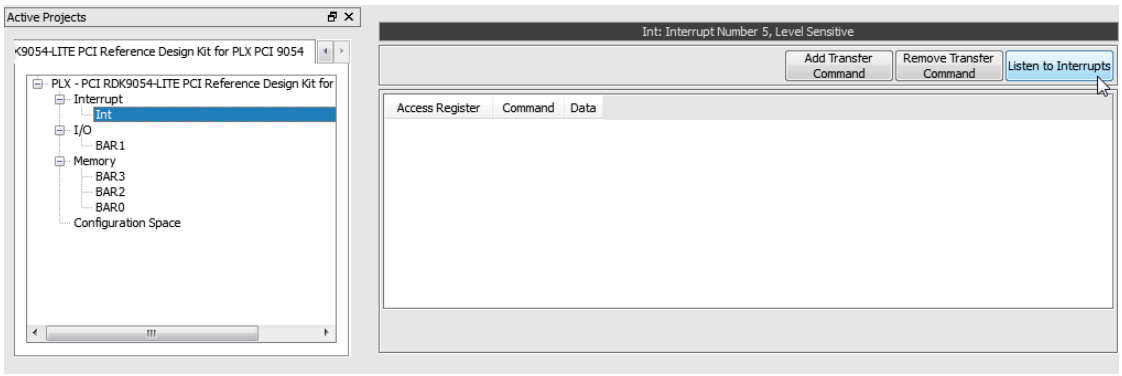
- Read and write to the I/O ports, memory space and your defined registers, as demonstrated in Figure 4.6.

Figure 4.6. Read/Write Memory and I/O



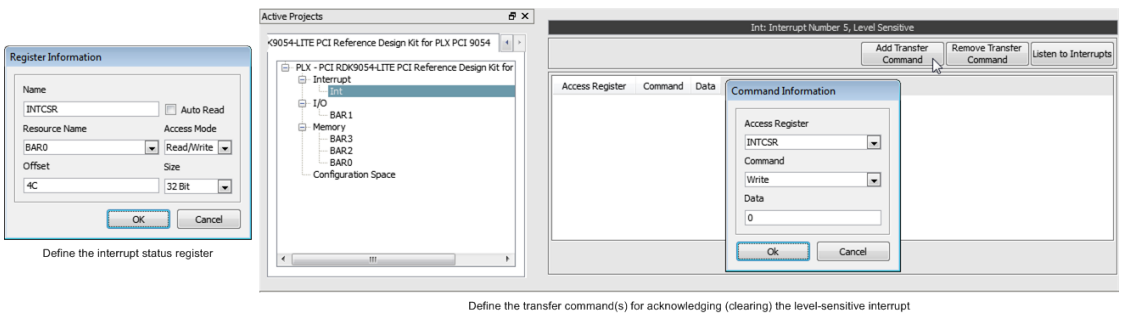
- 'Listen' to your hardware's interrupts.

Figure 4.7. Listen to Interrupts



For level-sensitive interrupts, such as legacy PCI interrupts, you must use DriverWizard to define the interrupt status register and assign the read/write command(s) for acknowledging (clearing) the interrupt, before attempting to listen to the interrupts with the wizard, otherwise the OS may hang! Figure 4.8 below demonstrates how to define an interrupt acknowledgment command for a defined `INTCSR` hardware register. Note, however, that interrupt acknowledgment information is hardware-specific.

Figure 4.8. Define Transfer Commands for Level-Sensitive Interrupts

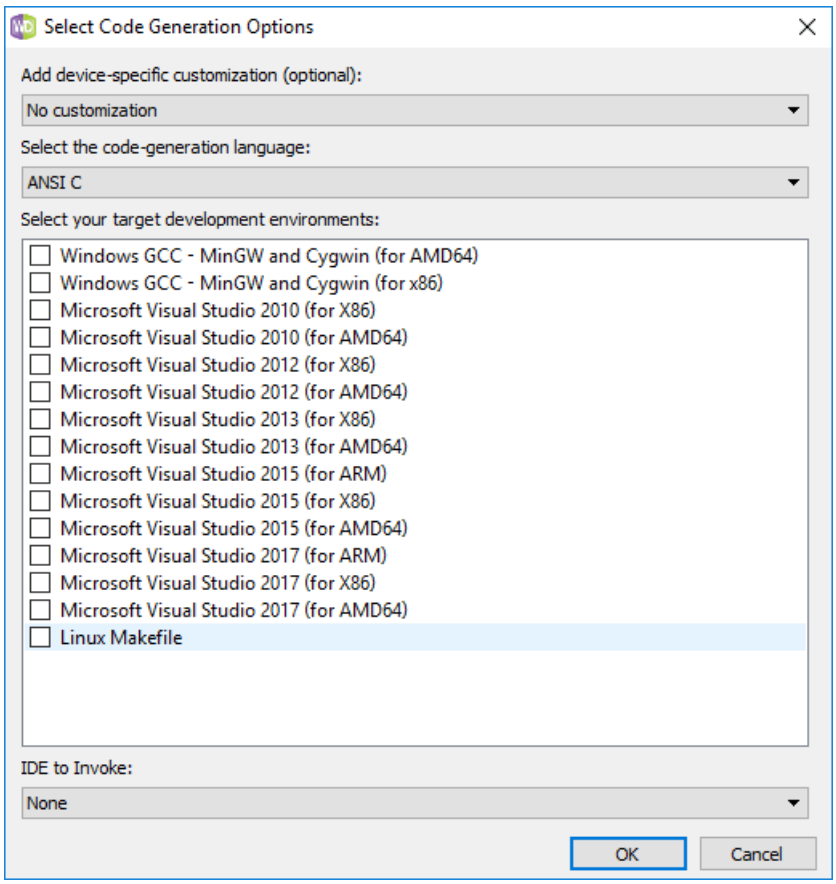


6. **Generate the skeletal driver code:**

   a. Select to generate code either via the **Generate Code** toolbar icon or from the **Project | Generate Code** menu.

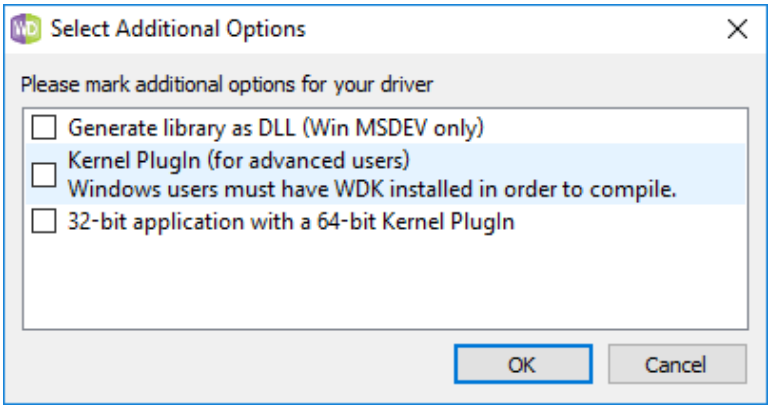
b. In the **Select Code Generation Options** dialogue box that will appear, you may optionally select to generate additional customized code for one of the supported devices [7]; then choose the code language and development environment(s) for the generated code and select **Next** to generate the code.

Figure 4.9. Code Generation Options



c. Click **Next** and select whether to handle handle Plug-and-Play and power management events from within your driver code, whether to generate Kernel PlugIn code [11] (and what type of related application to create), and whether to build your project's library as a DLL (for MS Visual Studio Windows projects).

Figure 4.10. Additional Driver Options



Kernel PlugIn Windows Project Notes

- To compile the generated Kernel PlugIn code, the Windows Driver Kit (WDK) must be installed.
- To successfully build a Kernel PlugIn project using MS Visual Studio, the path to the project directory must not contain any spaces.

d. Save your project (if required) and click **OK** to open your development environment with the generated driver.

e. Close DriverWizard to avoid device overlap errors.

7. **Compile and run the generated code:**

   - Use this code as a starting point for your device driver. Modify where needed to perform your driver's specific functionality.
   - The source code DriverWizard creates can be compiled with any 32-bit compiler, and will run on all supported platforms without modification.

   For detailed compilation instructions, refer to Section 4.2.2.

4.2.1. Automatic Code Generation

After you have finished diagnosing your device and have ensured that it runs according to your specifications, you are ready to write your driver.

4.2.1.1. Generating the Code

Generate code by selecting this option either via DriverWizard's **Generate Code** toolbar icon or from the wizard's **Project | Generate Code** menu (see Section 4.2, Step 6). DriverWizard will generate the source code for your driver, and save it together with the wizard driver-project file (**xxx.wdp**, where "xxx" is the project name). The files are saved in a directory DriverWizard creates for every development environment and operating system selected in the code generation dialogue.

4.2.1.2. The Generated PCI/ISA C Code

In the source code directory you now have a new **xxx_lib.h** file, which contains type definitions and functions declarations for the API created for you by the DriverWizard, and an **xxx_lib.c** source file, which contains the implementation of the generated device-specific API.
In addition, you will find an **xxx_diag.c** source file, which includes a `main`() function and implements a sample diagnostics application that utilizes the generated DriverWizard API to communicate with your device.

The code generated by DriverWizard is composed of the following elements and files, where **xxx** represents your DriverWizard project name:

- Library functions for accessing each element of your card's resources (memory ranges and I/O, registers and interrupts):
  - **xxx_lib.c** — the implementation of the hardware-specific API (declared in **xxx_lib.h**), using the WinDriver Card (WDC) API [B.2].
  - **xxx_lib.h** — a header file that contains type definitions and function declarations for the API implemented in the **xxx_lib.c** source file.
    You should include this file in your source code to use the API generated by DriverWizard for your device.
- A diagnostics program that utilizes the generated DriverWizard API (declared in **xxx_lib.h**) to communicate with your device(s):
  - **xxx_diag.c** The source code of the generated diagnostics console application.
    Use this diagnostics program as your skeletal device driver.
- A list of all files created can be found at **xxx_files.txt**.

After creating your code, compile it with your favorite compiler, and see it work!

Change the function `main`() of the program so that the functionality suits your needs.

4.2.1.3. The Generated PCI/ISA Python Code

In the source code directory you now have a new **xxx_lib.py** file, which contains type definitions and function implementations for the API created for you by the DriverWizard. In addition, you will find an **xxx_diag.py** source file, which includes a `main`() function and implements a sample diagnostics application that utilizes the generated DriverWizard API to communicate with your device. The **wdlib** subdirectory includes shared Python code files that implement the WinDriver API structs, import the WinDriver user API DLL file, define variables, and implement user I/O functions required for the user application to run. The code generated by DriverWizard is composed of the following elements and files, where **xxx** represents your DriverWizard project name:

- Library functions for accessing each element of your card's resources (memory ranges and I/O, registers and interrupts):
  - **xxx_lib.py** — type definitions and the implementation of the hardware-specific API, using the WinDriver Card (WDC) API [B.2].
- A diagnostics program that utilizes the generated DriverWizard API (declared in **xxx_lib.py**) to communicate with your device(s):
  - **xxx_diag.py** The source code of the generated diagnostics console application. Use this diagnostics program as your skeletal device driver.

- A list of all files created can be found at **xxx_files.txt**.

After creating your code, run it with your favorite Python interpreter and see it work!

Change the function `main`() of the program so that the functionality suits your needs.

4.2.1.4. The Generated PCI/ISA C#.NET Code

In the source code directory you now have a new **lib** subdirectory, which contains type definitions and function implementations for the API created for you by the DriverWizard. This subdirectory outputs a DLL file that is compiled by the **xxx_diag** project. In addition, you will find a **diag** subdirectory, a sample diagnostics application that utilizes the generated DriverWizard API to communicate with your device. The **xxx_diag.cs** file that includes a `Main`() function. A list of all files created can be found at **xxx_files.txt**.

After creating your code, compile it with your favorite C# compiler and see it work!

Change the function `Main`() of the program so that the functionality suits your needs.

4.2.2. Compiling the Generated Code

4.2.2.1. Windows Compilation

As explained above, on Windows you can select to generate project, solution, and make files for the supported compilers and development environments — MS Visual Studio, Windows GCC (MinGW/Cygwin).
For integrated development environments (IDEs), such as MS Visual Studio, you can also select to automatically invoke your selected IDE from the wizard. You can then proceed to immediately build and run the code from your selected IDE.

You can also build the generated code using any other compiler or development environment that supports the selected code language and target OS. Simply create a new project or make file for your selected compiler/environment, include the generated source files, and run the code.

- For Windows, the generated compiler/environment files are located under an **x86** directory — for 32-bit projects — or an **amd64** directory — for 64-bit projects.

To build a Kernel PlugIn project (on Windows), follow the instructions in Section 12.8.1.

4.2.2.1.1. Running compiled code under Windows 10 IoT Core

Since Windows 10 IoT Core currently does not support WinForms applications, the DriverWizard generated code in C#/Visual Basic (which use these libraries) will not run on this environment. However, you can import **wdapi_dotnet1281.dll** and use it in a console mode C#/VB.Net Application you develop.

1. Copy **wdapi1281.dll** from **WinDriver\redist**. Make sure you are using the suitable version for your platform (x86/x64/ARM).

2. Compile your code on the development computer. Make sure you compile it to suit your target platform.

3. Copy your compiled binary to your Windows 10 IoT Core target computer and run it using SSH.

4.2.2.2. Linux Compilation

Use the makefile that was created for you by DriverWizard in order to build the generated code using your favorite compiler, preferably GCC.

To build a Kernel PlugIn project, follow the instructions in Section 12.8.2.

Chapter 5
Developing a Driver

This chapter takes you through the WinDriver driver development cycle.

5.1. Using DriverWizard to Build a Device Driver

- Use DriverWizard to diagnose your device and verify that it operates as expected: Read/write the I/O and memory ranges, view the PCI configuration registers, define and access custom registers, and listen to interrupts.

- Use DriverWizard to generate skeletal code for your device in C or C#. For more information about DriverWizard, refer to Chapter 4.

If you are using an enhanced-support PCI device (PLX 6466, 9030, 9050, 9052, 9054, 9056, 9080 and 9656; Altera Qsys design; Xilinx BMD design; Xilinx XDMA design), you may want to use the related WinDriver sample as the basis for your development instead of generating code with DriverWizard. Note that for devices based on the Altera Qsys design, Xilinx BMD design or Xilinx XDMA design, you can use DriverWizard to generate customized device-specific code, which utilizes the enhanced-support sample APIs. For additional information, refer to Chapter 7: *Enhanced Support for Specific Chipsets*.

- Use any C or .NET compiler or development environment (depending on the code you created) to build the skeletal driver you need.
  WinDriver provides specific support for the following environments and compilers: MS Visual Studio, C++, GCC, Windows GCC

That is all you need to do in order to create your user-mode driver.
If you discover that better performance is needed, refer to Chapter 10.
For a detailed description of WinDriver's PCI/ISA API, refer to Appendix B.
To learn how to perform operations that DriverWizard cannot automate, refer to Chapter 9.

5.2. Writing the Device Driver Without DriverWizard

There may be times when you choose to write your driver directly, without using DriverWizard. In such cases, either follow the steps outlined in this section to create a new driver project, or select a WinDriver sample that most closely resembles your target driver and modify it to suit your specific requirements.

5.2.1. Include the Required WinDriver Files

1. Include the relevant WinDriver header files in your driver project.
   All header files are found under the **WinDriver/include** directory.

   All WinDriver projects require the **windrvr.h** header file.
   When using the `WDC_xxx` API [B.2], include the **wdc_lib.h** and **wdc_defs.** header files (these files already include **windrvr.h**).

   Include any other header file that provides APIs that you wish to use from your code (e.g., files from the **WinDriver/samples/shared** directory, which provide convenient diagnostics functions.)

2. Include the relevant header files from your source code: For example, to use API from the **windrvr.h** header file, add the following line to the code:

   ```
   #include "windrvr.h"
   ```

3. Link your code with the WDAPI library (Windows) / shared object (Linux):

   - For Windows: **WinDriver\lib\<CPU>\wdapi1281.lib**, where the **<CPU>** directory is either **x86** (32-bit binaries for x86 platforms), **amd64** (64-bit binaries for x64 platforms), or **amd64\x86** (32-bit binaries for x64 platforms [A.2]

   - For Linux: From the **WinDriver/lib** directory — **libwdapi1281.so** or **libwdapi1281_32.so** (for 32-bit applications targeted at 64-bit platforms)
     Note: When using **libwdapi1281_32.so**, first create a copy of this file in a different directory and rename it to **libwdapi1281.so**, then link your code with the renamed file [A.2].

   You can also include the library's source files in your project instead of linking the project with the library. The C source files are located under the **WinDriver/src/wdapi** directory.

When linking your project with the WDAPI library/framework/shared object, you will need to distribute this binary with your driver.
For Windows, get **wdapi1281.dll** / **wdapi1281_32.dll** (for 32-bit applications targeted at 64-bit platforms) from the **WinDriver\redist** directory.
For Linux, get **libwdapi1281.so** / **libwdapi1281_32.so** (for 32-bit applications targeted at 64-bit platforms) from the **WinDriver/lib** directory.

Note: On Windows and Linux, when using the DLL/shared object file for 32-bit applications on 64-bit platforms (**wdapi1281_32.dll** / **libwdapi1281_32.so**), rename the copy of the file in the distribution package, by removing the **_32** portion [A.2].
For detailed distribution instructions, refer to Chapter 14.

4. Add any other WinDriver source files that implement API that you which to use in your code (e.g., files from the **WinDriver/samples/shared** directory.)

5.2.2. Write Your Code

This section outlines the calling sequence when using the `WDC_xxx` API [B.2].

1. Call `WDC_DriverOpen`() [B.3.2] to open a handle to WinDriver and the WDC library, compare the version of the loaded driver with that of your driver source files, and register your WinDriver license (for registered users).

2. For PCI/PCI Express devices, call `WDC_PciScanDevices`() [B.3.4] to scan the PCI bus and locate your device.

3. For PCI/PCI Express devices, call `WDC_PciGetDeviceInfo`() [B.3.16] to retrieve the resources information for your selected device.
   For ISA devices, define the resources yourself within a `WD_CARD` structure.

4. Call `WDC_PciDeviceOpen`() [B.3.17] / `WDC_IsaDeviceOpen`() [B.3.18] (depending on your device), and pass to the function the device's resources information. These functions return a handle to the device, which you can later use to communicate with the device using the `WDC_xxx` API.

5. Communicate with the device using the `WDC_xxx` API (see the description in Appendix B).
   To enable interrupts, call `WDC_IntEnable`() [B.3.48].
   To register to receive notifications for Plug-and-Play and power management events, call `WDC_EventRegister`() [B.3.52].

6. When you are done, call `WDC_IntDisable`() [B.3.49] to disable interrupt handling (if previously enabled), call `WDC_EventRegister`() [B.3.52] to unregister Plug-and-Play and power management event handling (if previously registered), and then call `WDC_PciDeviceClose`() [B.3.19] / `WDC_IsaDeviceClose`() [B.3.20] (depending on your device) in order to close the handle to the device.

7. Call `WDC_DriverClose`() [B.3.3] to close the handles to WinDriver and the WDC library.

5.2.3. Configure and Build Your Code

After including the required files and writing your code, make sure that the required build flags and environment variables are set, then build your code.

When developing a driver for a 64-bit platform [A], your project or makefile must include the **`KERNEL_64BIT`** preprocessor definition. In the makefiles, the definition is added using the `-D` flag: `-DKERNEL_64BIT`. (The sample and wizard-generated Linux and Windows GCC makefiles and the Windows MS Visual Studio projects, in the 64-bit WinDriver toolkit, already include this definition.)

Before building your code, verify that the `WD_BASEDIR` environment variable is set to the location of the of the WinDriver installation directory.
On Windows and Linux you can define the `WD_BASEDIR` environment variable globally — as explained in Chapter 3: For Windows — refer to the Windows WD_BASEDIR note in Section 3.2.1; for Linux: refer to Section 3.2.2.2, Step 8.

Chapter 6
Debugging Drivers

The following sections describe how to debug your hardware-access application code.

6.1. User-Mode Debugging

- Since WinDriver is accessed from the user mode, we recommend that you first debug your code using your standard debugging software.
- The Debug Monitor utility [6.2] logs debug messages from WinDriver's kernel-mode and user-mode APIs. You can also use WinDriver APIs to send your own debug messages to the Debug Monitor log.
- When using WinDriver's API (such as `WD_Transfer()` — see the **WinDriver PCI Low-Level API Reference**), to read/write memory ranges on the card in the kernel, while the Debug Monitor [6.2] is activated, WinDriver's kernel module validates the memory ranges, i.e., it verifies that the reading/writing from/to the memory is in the range that is defined for the card.
- Use DriverWizard to check values of memory and registers in the debugging process.

6.2. Debug Monitor

Debug Monitor is a powerful graphical- and console-mode tool for monitoring all activities handled by the WinDriver kernel.
You can use this tool to monitor how each command sent to the kernel is executed.

In addition, WinDriver enables you to print your own debug messages to the Debug Monitor, using the `WD_DebugAdd()` function (described in the **WinDriver PCI Low-Level API Reference**) or the high-level `PrintDbgMessage()` function [B.10.15].

The Debug Monitor comes in two versions:

- **wddebug_gui** [6.2.1] — a GUI version for Windows and Linux.
- **wddebug** [6.2.2] — a console-mode version for Windows, and Linux.

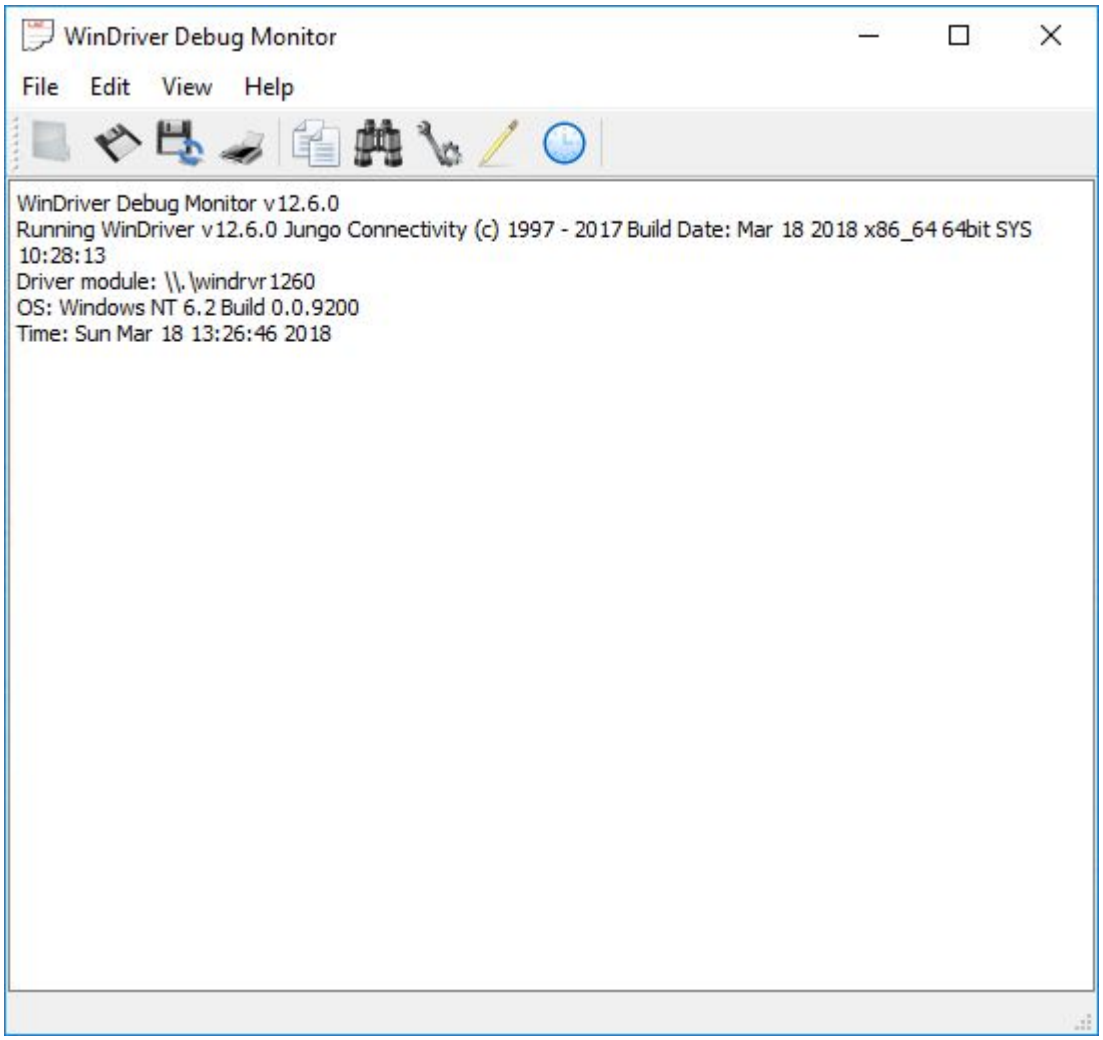
Both Debug Monitor versions are provided in the **WinDriver/util** directory

6.2.1. The wddebug_gui Utility

wddebug_gui is a fully graphical (GUI) version of the Debug Monitor utility for Windows and Linux.

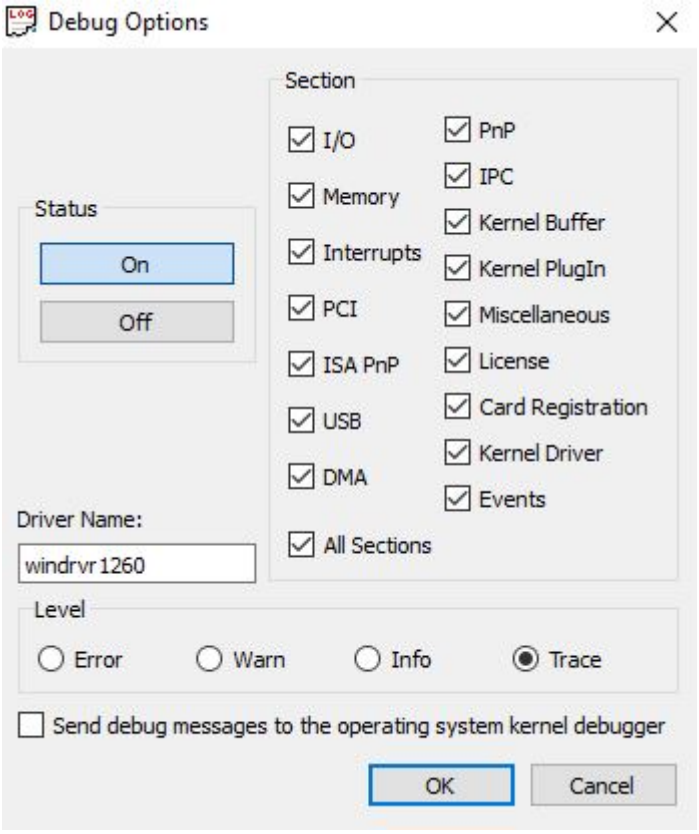
1. Run the Debug Monitor using either of the following methods:
   - Run **WinDriver/util/wddebug_gui**
   - Run the Debug Monitor from DriverWizard's **Tools** menu.
   - On Windows, run **Start | Programs | WinDriver | Debug Monitor**.

Figure 6.1. Start Debug Monitor



2. Set the Debug Monitor's status, trace level and debug sections information from the **Debug Options** dialogue, which is activated either from the Debug Monitor's **View | Debug Options** menu or the **Debug Options** toolbar button.

Figure 6.2. Debug Options



- **Status** — Set trace on or off.
- **Section** — Choose what part of the WinDriver API you would like to monitor.

  For example, if you are experiencing problems with the interrupt handler on your PCI card, select the **PCI** and **Interrupts** sections.

  Choose carefully those sections that you would like to monitor. Checking more options than necessary could result in an overflow of information, making it harder for you to locate your problem.

- **Level** — Choose the level of messages you want to see for the resources defined.
  - **Error** is the lowest trace level, resulting in minimum output to the screen.
  - **Trace** is the highest trace level, displaying every operation the WinDriver kernel performs.
- **Send debug messages to the operating system kernel debugger** —

  Select this option to send the debug messages received from the WinDriver kernel module to an external kernel debugger, in addition to the Debug Monitor.

On Windows 7 and higher, the first time that you enable this option you will need to restart the PC.

A free Windows kernel debugger, WinDbg, is distributed with the Windows Driver Kit (WDK) and is part of the Debugging Tools for Windows package, distributed via the Microsoft web site.

- **Driver Name** —

  This field displays the name of the driver currently being debugged. Changing it allows you to debug a renamed WinDriver driver.

3. Once you have defined what you want to trace and on what level, click **OK** to close the **Debug Options** window.

4. Optionally make additional configurations via the Debug Monitor menus and toolbar.

When debugging OS crashes or hangs, it's useful to auto-save the Debug Monitor log, via the **File –> Toggle Auto-Save** menu option (available also via a toolbar icon), in addition to sending the debug messages to the OS kernel debugger (see Step 2).

5. Run your application (step-by-step or in one run).

You can use the **Edit –> Add Custom Message...** menu option (available also via a toolbar icon) to add custom messages to the log. This is especially useful for clearly marking different execution sections in the log.

6. Watch the Debug Monitor log (or the kernel debugger log, if enabled) for errors or any unexpected messages.

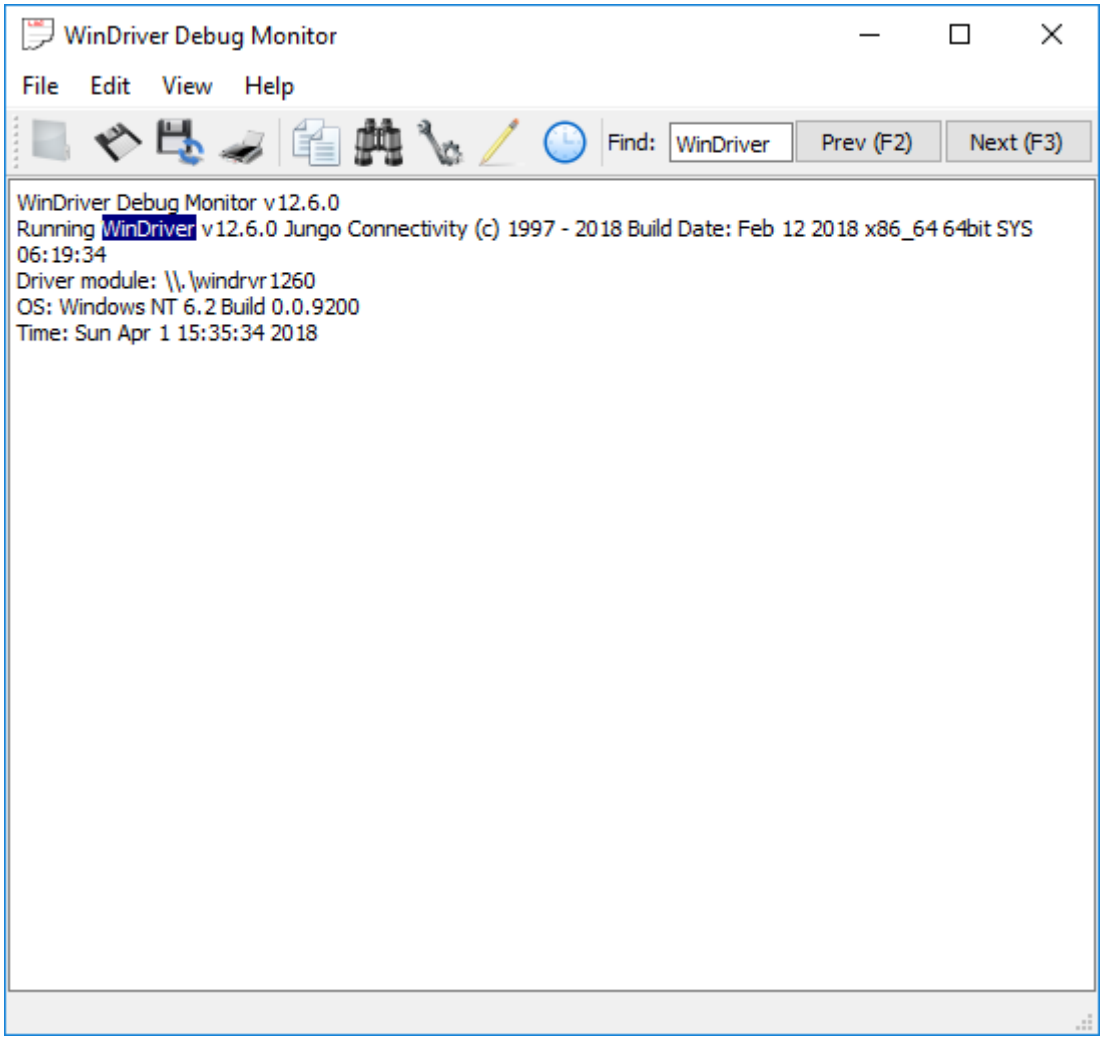
6.2.1.1. Search in wddebug_gui

wddebug_gui allows to find expressions in the Debug output in 4 ways:

1. Starting to type an expression with the keyboard immediately searches for it in the Debug output.
2. Pressing **CTRL+F** displays the Find field in the toolbar
3. Clicking the **Find** icon in the toolbar.
4. Going to **Edit->Find...**

If an expression is found it is marked. It is possible to browse between occurences of an expression using **Prev (F2)** and **Next (F3)**.

Figure 6.3. Search in wddebug_gui



6.2.1.2. Opening Windows kernel crash dump with wddebug_gui

In driver development, it is not uncommon to experience kernel crashes that lead to the Blue Screen of Death (BSOD). In order to assist developers in debugging and solving these crashes, WinDriver allows saving its kernel debug messages in the memory dump that Windows automatically creates when the system crashes. These crash dumps can later be opened in **wddebug_gui** after the system was restarted.

1. Make sure **Send debug messages to the operating system kernel debugger** is checked in the **Options** window before reproducing the crash.

2. Load up the WinDriver symbols by going to **File->Symbol File Path...** and loading your driver's symbols **MyDriver.pdb**(the file name for the default driver is **lib/windrvr1281.pdb**). Do not skip this step, otherwise the kernel dump might not be comprehensible.

3. Load the kernel crash dump (.dmp) file by going to **File->Process Kernel Dump...**. **wddebug_gui** will display the output from the crash dump.

6.2.1.3. Running wddebug_gui for a Renamed Driver

By default, **wddebug_gui** logs messages from the default WinDriver kernel module — **windrvr1281.sys/.dll/.o/.ko**. However, you can also use **wddebug_gui** to log debug messages from a renamed version of this driver [15.2], in two ways:

1. From within **wddebug_gui**, By going to **View->Debug Options** and changing the value of the "Driver name" field to your own renamed driver's name.

2. By running **wddebug_gui** from the command line with the **`driver_name`** argument: **`wddebug_gui <driver_name>`**.

The driver name should be set to the name of the driver file without the file's extension; e.g., **windrvr1281**, not **windrvr1281.sys** (on Windows) or **windrvr1281.o** (on Linux).

For example, if you have renamed the default **windrvr1281.sys** driver on Windows to **my_driver.sys**, you can log messages from your driver by running the Debug Monitor using the following command: **`wddebug_gui my_driver`**

6.2.2. The wddebug Utility

6.2.2.1. Console-Mode wddebug Execution

The **wddebug** version of the Debug Monitor utility can be executed as a console-mode application on all supported operating systems: Windows, and Linux. To use the console-mode Debug Monitor version, run **WinDriver/util/wddebug** in the manner explained below.

wddebug console-mode usage

```
wddebug [<driver_name>] [<command>] [<level>] [<sections>]
```

The **wddebug** arguments must be provided in the order in which they appear in the usage statement above.

- **`<driver_name>`** — The name of the driver to which to apply the command.

  The driver name should be set to the name of the WinDriver kernel module — **windrvr1281** (default), or a renamed version of this driver (refer to the explanation in Section 15.2).

The driver name should be set to the name of the driver file without the file's extension; e.g., **windrvr1281**, *not* **windrvr1281.sys** (on Windows) or **windrvr1281.o** (on Linux).

- **`<command>`** — The Debug Monitor command to execute:
  - Activation commands:
    - **`on`** — Turn the Debug Monitor on.
    - **`off`** — Turn the Debug Monitor off.
    - **`dbg_on`** — Redirect the debug messages from the Debug Monitor to a kernel debugger and turn the Debug Monitor on (if it was not already turned on).

On Windows 7 and higher, the first time that you enable this option you will need to restart the PC.

    - **`dbg_off`** — Stop redirecting debug messages from the Debug Monitor to a kernel debugger.

The **`on`** and **`dbg_on`** commands can be used together with the **`<level>`** and **`<sections>`** arguments.

  - **`dump`** — Continuously send ("dump") debug information to the command prompt, until the user selects to stop (by following the instructions displayed in the command prompt).
  - **`status`** — Display information regarding the running driver (**`<driver_name>`**), the current Debug Monitor status — including the active debug level and sections (when the Debug Monitor is on) — and the size of the debug-messages buffer.
  - **`clock_on`** — Add a timestamp to each debug message. The timestamps are relative to the driver-load time, or to the time of the last **`clock_reset`** command.
  - **`clock_off`** — Do not add timestamps to the debug messages.
  - **`clock_reset`** — Reset the debug-messages timestamps clock.

- **sect_info_on** — Add section(s) information to each debug message.
- **sect_info_off** — Do not add section(s) information to the debug messages.
- **help** — Display usage instructions.
- No arguments (including no commands) — This is equivalent to running '**wddebug help**'.

The following arguments are applicable only with the **on** or **dbg_on** commands:

- **<level>** — The debug trace level to set — one of the following flags: **ERROR**, **WARN**, **INFO**, or **TRACE** (default).
  ERROR is the lowest trace level and TRACE is the highest level (displays all messages).

  
  When the **<sections>** argument is set, the **<level>** argument must be set as well (no default).

- **<sections>** — The debug sections — i.e., the WinDriver API sections — to monitor.
  This argument can be set either to **ALL** (default) — to monitor all the supported debug sections — or to a quoted string that contains a combination of any of the supported debug-section flags (run '**wddebug help**' to see the full list).

Usage Sequence

To log messages using **wddebug**, use the following sequence:

- Turn on the Debug Monitor by running **wddebug** with either the **on** or **dbg_on** command; the latter redirects the debug messages to the OS kernel debugger before turning on the Debug Monitor.

  You can use the **<level>** and **<sections>** arguments to set the debug level and sections for the log. If these arguments are not explicitly set, the default values will be used; (note that if you set the sections you must also set the level).

  You can also log messages from a renamed WinDriver driver by preceding the command with the name of the driver (default: **windrvr1281**) — see the **<driver_name>** argument.

- If you did not select to redirect the debug messages to the OS kernel debugger (using the **dbg_on** command), run **wddebug** with the **dump** command to begin dumping debug messages to the command prompt.
  You can turn off the display of the debug messages, at any time, by following the instructions displayed in the command prompt.

- Run applications that use the driver, and view the debug messages as they are being logged to the command prompt/the kernel debugger.

- At any time while the Debug Monitor is running, you can run **wddebug** with the following commands:

- **status**, **clock_on**, **clock_off**, **clock_reset**, **sect_info_on**, or **sect_info_off**,
- **on** or **dbg_on** with different **<level>** and/or **<sections>** arguments
- **dbg_on** and **dbg_off** — to toggle the redirection of debug messages to the OS kernel debugger
- **dump** — to start a new dump of the debug log to the command prompt; (the dump can be stopped at any time by following the instructions in the prompt)

- When you are ready, turn off the Debug Monitor by running **wddebug** with the **off** command.

The **status** command can be used to view information regarding the running WinDriver driver even when the Debug Monitor is off.

Example

The following is an example of a typical **wddebug** usage sequence. Since no **<driver_name>** is set, the commands are applied to the default driver — **windrvr1281**.

- Turn the Debug Monitor on with the highest trace level for all sections:
  wddebug on TRACE ALL

This is the same as running '**wddebug on TRACE**', because **ALL** is the default <sections> value.

- Dump the debug messages continuously to the command prompt or a file, until the user selects to stop:
  wddebug dump
  wddebug dump <filename>
- Use the driver and view the debug messages in the command prompt.
- Turn the Debug Monitor off:
  wddebug off

6.2.2.2. Debugging in Windows 10 IoT Core

In order to debug your WinDriver application and driver under Windows 10 IoT Core:

1. Copy **WinDriver\samples\wddebug\wddebug.exe** to your Windows 10 IoT Core device.
2. Run **wddebug dump** from your target device (Preferrably using your SSH terminal).
3. Run your application.
4. Stop **wddebug** utility using **CTRL+C**.

Chapter 7
Enhanced Support for Specific Chipsets

7.1. Overview

In addition to the standard WinDriver APIs and the DriverWizard code generation capabilities described in this manual, which support development of drivers for any PCI/ISA device, WinDriver features enhanced support for specific PCI chipsets. This enhanced support includes custom APIs, customized code generation (for some of the chipsets), and sample diagnostics code, which are all designed specifically for these chipsets.

WinDriver's enhanced support is currently available for the following PCI chipsets: PLX 6466, 9030, 9050, 9052, 9054, 9056, 9080 and 9656; Altera Qsys design; Xilinx BMD design; Xilinx XDMA design.
Customized code generation is available for the Altera Qsys design, Xilinx BMD design and Xilinx XDMA design chipsets.

7.2. Developing a Driver Using the Enhanced Chipset Support

When developing a driver for a device based on one of the enhanced-support chipsets [7.1], you can use WinDriver's chipset-set specific support in the following manner: If your device is based on the Altera Qsys design, Xilinx BMD design or Xilinx XDMA design, you can generate customized code for the device by selecting this option in the DriverWizard code generation options dialogue (see Section 4.2, Step 6.b). Alternatively, or if you are using another enhanced-support device, follow the steps below to use one the enhanced-support WinDriver samples as the starting point for your development:

1. Locate the sample diagnostics program for your device under the **WinDriver/chip_vendor/chip_name** directory.

   Most of the sample diagnostics programs are named **xxx_diag** and their source code is normally found under an **xxx_diag** subdirectory. The program's executable is found under a subdirectory for your target operating system (e.g., **WIN32** for Windows.)

2. Run the custom diagnostics program to diagnose your device and familiarize yourself with the options provided by the sample program.

3. Use the source code of the diagnostics program as your skeletal device driver and modify the code, as needed, to suit your specific development needs. When modifying the code, you can utilize the custom WinDriver API for your specific chip. The custom API is typically found under the **WinDriver/chip_vendor/lib** directory.

4. If the user-mode driver application that you created by following the steps above contains parts that require enhanced performance (e.g., an interrupt handler), you can move the relevant portions of your code to a Kernel PlugIn driver for optimal performance, as explained in Chapter 11.

Chapter 8
PCI Express

8.1. PCI Express Overview

The PCI Express (**PCIe**) bus architecture (formerly 3GIO or 3rd Generation I/O) was introduced by Intel, in partnership with other leading companies, including IBM, Dell, Compaq, HP and Microsoft, with the intention that it will become the prevailing standard for PC I/O in the years to come.

PCI Express allows for larger bandwidth and higher scalability than the standard PCI 2.2 bus.

The standard PCI 2.2 bus is designed as a single parallel data bus through which all data is routed at a set rate. The bus shares the bandwidth between all connected devices, without the ability to prioritize between devices. The maximum bandwidth for this bus is 132MB/s, which has to be shared among all connected devices.

PCI Express consists of serial, point-to-point wired, individually clocked 'lanes', each lane consisting of two pairs of data lines that can carry data upstream and downstream simultaneously (full-duplex). The bus slots are connected to a switch that controls the data flow on the bus. A connection between a PCI Express device and a PCI Express switch is called a 'link'. Each link is composed of one or more lanes. A link composed of a single lane is called an x1 link; a link composed of two lanes is called an x2 link; etc. PCI Express supports x1, x2, x4, x8, x12, x16, and x32 link widths (lanes). The PCI Express architecture allows for a maximum bandwidth of approximately 500MB/s per lane. Therefore, the maximum potential bandwidth of this bus is 500MB/s for x1, 1,000MB/s for x2, 2,000MB/s for x4, 4,000MB/s for x8, 6,000MB/s for x12, and 8,000MB/s for x16. These values provide a significant improvement over the maximum 132MB/s bandwidth of the standard 32-bit PCI bus. The increased bandwidth support makes PCI Express ideal for the growing number of devices that require high bandwidth, such as hard drive controllers, video streaming devices and networking cards.

The usage of a switch to control the data flow in the PCI Express bus, as explained above, provides an improvement over a shared PCI bus, because each device essentially has direct access to the bus, instead of multiple components having to share the bus. This allows each device to use its full bandwidth capabilities without having to compete for the maximum bandwidth offered by a single shared bus. Adding to this the lanes of traffic that each device has access to in the PCI Express bus, PCI Express truly allows for control of much more bandwidth than previous PCI technologies. In addition, this architecture enables devices to communicate with each other directly (peer-to-peer communication).

In addition, the PCI Express bus topology allows for centralized traffic-routing and resource-management, as opposed to the shared bus topology. This enables PCI Express to support quality

of service (QoS): The PCI Express switch can prioritize packets, so that real-time streaming packets (i.e., a video stream or an audio stream) can take priority over packets that are not as time critical.

Another main advantage of the PCI Express is that it is cost-efficient to manufacture when compared to PCI and AGP slots or other new I/O bus solutions such as PCI-X.

PCI Express was designed to maintain complete hardware and software compatibility with the existing PCI bus and PCI devices, despite the different architecture of these two buses.

As part of the backward compatibility with the PCI 2.2 bus, legacy PCI 2.2 devices can be plugged into a PCI Express system via a PCI Express-to-PCI bridge, which translates PCI Express packets back into standard PCI 2.2 bus signals. This bridging can occur either on the motherboard or on an external card.

8.2. WinDriver for PCI Express

WinDriver fully supports backward compatibility with the standard PCI features on PCI Express boards. The wide support provided by WinDriver for the standard PCI bus — including a rich set of APIs, code samples and the graphical DriverWizard for hardware debugging and driver code generation — is also applicable to PCI Express devices, which by design are backward compatible with the legacy PCI bus.

You can also use WinDriver's PCI API to easily communicate with PCI devices connected to the PC via PCI Express-to-PCI bridges and switches (e.g., the PLX 8111/8114 bridges or the PLX 8532 switch, respectively).

In addition, WinDriver provides you with a set of APIs for easy access to the PCI Express extended configuration space on target platforms that support such access (e.g., Windows and Linux) — see the description of the `WDC_PciReadCfgXXX`() and `WDC_PciWriteCfgXXX`() functions in Sections B.3.32–B.3.39 of the present manual, or the description of the lower-level `WD_PciConfigDump`() function in the **WinDriver PCI Low-Level API Reference**.

On Linux and Windows 7 and higher, the WinDriver interrupt handling APIs also support Message-Signaled Interrupts (MSI) and Extended Message-Signaled Interrupts (MSI-X), as detailed in Section 9.2 of the manual.

WinDriver also features enhanced support for PCI Express cards that are based on the Xilinx Bus Master DMA (BMD) design or the Altera Qsys design. The WinDriver **WinDriver/xilinx/bmd_design** and **WinDriver/altera/qsys_design** directories each contain library APIs and a sample user-mode diagnostic applications for communicating with the respective device type, including DMA and MSI handling code. The Xilinx BMD directory also contains sample Kernel PlugIn driver code [11]. In addition, the DriverWizard can be used to generate customized code for such cards [7].

Chapter 9
Advanced Issues

This chapter covers advanced driver development issues and contains guidelines for using WinDriver to perform tasks that cannot be fully automated by the DriverWizard.

Note that WinDriver's enhanced support for specific chipsets [7] includes custom APIs for performing hardware-specific tasks like DMA and interrupt handling, thus freeing developers of drivers for these chipsets from the need to implement the code for performing these tasks themselves.

9.1. Performing Direct Memory Access (DMA)

This section describes how to use WinDriver to implement bus-master Direct Memory Access (**DMA**) for devices capable of acting as bus masters. Such devices have a DMA controller, which the driver should program directly.

DMA is a capability provided by some computer bus architectures — including PCI and PCIe — which allows data to be sent directly from an attached device to the memory on the host, freeing the CPU from involvement with the data transfer and thus improving the host's performance.

A DMA buffer can be allocated in two ways:

- **Contiguous buffer** — A contiguous block of memory is allocated.
- **Scatter/Gather** — The allocated buffer can be fragmented in the physical memory and does not need to be allocated contiguously. The allocated physical memory blocks are mapped to a contiguous buffer in the calling process's virtual address space, thus enabling easy access to the allocated physical memory blocks.

The programming of a device's DMA controller is hardware specific. Normally, you need to program your device with the *local address* (on your device), the *host address* (the physical memory address on your PC) and the *transfer count* (the size of the memory block to transfer), and then set the register that initiates the transfer.

WinDriver provides you with API for implementing both contiguous-buffer DMA and Scatter/Gather DMA (if supported by the hardware) — see the description of `WDC_DMAContigBufLock()` [B.3.40], `WDC_DMASGBufLock()` [B.3.41], and `WDC_DMABufUnlock()` [B.3.43]. (The lower-level `WD_DMAxxx` API is described in the **WinDriver PCI Low-Level API Reference**, but we recommend using the convenient wrapper `WDC_xxx` API instead.)

The following sections include code samples that demonstrate how to use WinDriver to implement Scatter/Gather DMA [9.1.1] and contiguous-buffer DMA [9.1.2], and an explanation on how to preallocate contiguous DMA buffers on Windows [9.1.2.1].

- The sample routines demonstrate using either an interrupt mechanism or a polling mechanism to determine DMA completion.
- The sample routines allocate a DMA buffer and enable DMA interrupts (if polling is not used) and then free the buffer and disable the interrupts (if enabled) for each DMA transfer. However, when you implement your actual DMA code, you can allocate DMA buffer(s) once, at the beginning of your application, enable the DMA interrupts (if polling is not used), then perform DMA transfers repeatedly, using the same buffer(s), and disable the interrupts (if enabled) and free the buffer(s) only when your application no longer needs to perform DMA.

9.1.1. Implementing Scatter/Gather DMA

Following is a sample routine that uses WinDriver's WDC API [B.2] to allocate a Scatter/Gather DMA buffer and perform bus-master DMA transfers.

C Example:

A more detailed example, which is specific to the enhanced support for PLX chipsets [7] can be found in the **WinDriver/plx/lib/plx_lib.c** library file and **WinDriver/plx/diag_lib/plx_diag_lib.c** diagnostics library file (which utilizes the **plx_lib.c** DMA API).

```
BOOL DMARoutine(WDC_DEVICE_HANDLE hDev, DWORD dwDMABufSize,
    UINT32 u32LocalAddr, BOOL fPolling, BOOL fToDev)
{
    PVOID pBuf;
    WD_DMA *pDma = NULL;
    BOOL fRet = FALSE;

    /* Allocate a user-mode buffer for Scatter/Gather DMA */
    pBuf = malloc(dwDMABufSize);
    if (!pBuf)
        return FALSE;

    /* Lock the DMA buffer and program the DMA controller */
    if (!DMAOpen(hDev, pBuf, u32LocalAddr, dwDMABufSize, fToDev, &pDma))
        goto Exit;

    /* Enable DMA interrupts (if not polling) */
    if (!fPolling)
    {
        if (!MyDMAInterruptEnable(hDev, MyDmaIntHandler, pDma))
            goto Exit; /* Failed enabling DMA interrupts */
    }

    /* Flush the CPU caches (see documentation of WDC_DMASyncCpu()) */
    WDC_DMASyncCpu(pDma);
```

```
    /* Start DMA - write to the device to initiate the DMA transfer */
    MyDMAStart(hDev, pDma);

    /* Wait for the DMA transfer to complete */
    MyDMAWaitForCompletion(hDev, pDma, fPolling);
    /* Flush the I/O caches (see documentation of WDC_DMASyncIo()) */
    WDC_DMASyncIo(pDma);

    fRet = TRUE;
Exit:
    DMAClose(hDev, pDma, fPolling);
    free(pBuf);
    return fRet;
}

/* DMAOpen: Locks a Scatter/Gather DMA buffer */
BOOL DMAOpen(WDC_DEVICE_HANDLE hDev, PVOID pBuf, UINT32 u32LocalAddr,
    DWORD dwDMABufSize, BOOL fToDev, WD_DMA **ppDma)
{
    DWORD dwStatus, i;
    DWORD dwOptions = fToDev ? DMA_TO_DEVICE : DMA_FROM_DEVICE;

    /* Lock a Scatter/Gather DMA buffer */
    dwStatus = WDC_DMASGBufLock(hDev, pBuf, dwOptions, dwDMABufSize, ppDma);
    if (WD_STATUS_SUCCESS != dwStatus)
    {
        printf("Failed locking a Scatter/Gather DMA buffer. Error 0x%lx - %s\n",
            dwStatus, Stat2Str(dwStatus));
        return FALSE;
    }

    /* Program the device's DMA registers for each physical page */
    MyDMAProgram((*ppDma)->Page, (*ppDma)->dwPages, fToDev, u32LocalAddr);

    return TRUE;
}

/* DMAClose: Unlocks a previously locked Scatter/Gather DMA buffer */
void DMAClose(WDC_DEVICE_HANDLE hDev, WD_DMA *pDma, BOOL fPolling)
{
    /* Disable DMA interrupts (if not polling) */
    if (!fPolling)
        MyDMAInterruptDisable(hDev);

    /* Unlock and free the DMA buffer */
    WDC_DMABufUnlock(pDma);
}
```

C# Example:

A more detailed example, which is specific to the enhanced support for PLX chipsets [7] can be found in the **WinDriver/plx/dotnet/lib/** library and **WinDriver/plx/dotnet/diag/** diagnostics library.

```
bool DMARoutine(PCI_Device dev, DWORD dwDMABufSize, UINT32 u32LocalAddr,
    bool fPolling, bool fToDev, IntHandler MyDmaIntHandler)
{
    bool fRet = false;
    IntPtr pBuf = IntPtr.Zero;
    Log log = new Log(new Log.TRACE_LOG(TraceLog),
        new Log.ERR_LOG(ErrLog));
    WD_DMA wdDma = new WD_DMA();
    DmaBuffer dmaBuf = new DmaBufferSG(dev, log);

    /* Allocate user mode buffer for Scatter/Gather DMA */
    pBuf = Marshal.AllocHGlobal((int)dwDMABufSize);
    if (pBuf == IntPtr.Zero)
    {
        fRet = false;
        goto Exit;
    }

    /* Lock the DMA buffer and program the DMA controller */
    if (!DMAOpen(ref dmaBuf, pBuf, u32LocalAddr, dwDMABufSize,
        fToDev, ref wdDma))
    {
        fRet = false;
        goto Exit;
    }

    /* Enable DMA interrupts (if not polling) */
    if (!fPolling)
    {
        if (!MyDMAInterruptEnable(dev, MyDmaIntHandler, ref wdDma))
        {
            fRet = false;
            goto Exit;  /* Failed enabling DMA interrupts */
        }
    }

    /* Flush the CPU caches (see documentation of WDC_DMASyncCpu()) */
    wdc_lib_decl.WDC_DMASyncCpu(dmaBuf.pWdDma);

    /* Start DMA - write to the device to initiate the DMA transfer */
    MyDmaStart(dev, ref wdDma);

    /* Wait for the DMA transfer to complete */
    MyDMAWaitForCompletion(dev, ref wdDma, fPolling);

    /* Flush the I/O caches (see documentation of WDC_DMASyncIo()) */
    wdc_lib_decl.WDC_DMASyncIo(dmaBuf.pWdDma);

    fRet = true;
```

```
Exit:
    DMAClose(dev, dmaBuf, fPolling);
    if (pBuf != IntPtr.Zero)
        Marshal.FreeHGlobal(pBuf);
    return fRet;
}

/* OpenDMA: Locks a Scatter/Gather DMA buffer */
public bool DMAOpen(ref DmaBuffer dmaBuf, IntPtr pBuf, UINT32 u32LocalAddr,
    DWORD bufSize, bool fToDev, ref WD_DMA wdDma)
{
    IntPtr pDma = dmaBuf.pWdDma;
    WDC_DEVICE_HANDLE hDev = dmaBuf.DeviceHandle;
    DWORD dwOptions = fToDev ? (DWORD)WD_DMA_OPTIONS.DMA_TO_DEVICE :
        (DWORD)WD_DMA_OPTIONS.DMA_FROM_DEVICE;

    wdDma = MarshalDMA(pDma);

    /* Lock a Scatter/Gather DMA buffer */
    if (wdc_lib_decl.WDC_DMASGBufLock(hDev, pBuf, dwOptions,
        bufSize, ref pDma) != (DWORD)wdc_err.WD_STATUS_SUCCESS)
        return false;

    /* Program the device's DMA registers for each physical page */
    MyDMAProgram(fToDev, wdDma.Page[0], wdDma.dwPages, u32LocalAddr);
    return true;
}

/* DMAClose: Unlocks a previously locked Scatter/Gather DMA buffer */
public void DMAClose(PCI_Device dev, DmaBuffer dmaBuf, bool fPolling)
{
    /* Disable DMA interrupts (if not polling) */
    if (!fPolling)
        MyDMAInterruptDisable(dev);

    /* Unlock and free the DMA buffer */
    wdc_lib_decl.WDC_DMABufUnlock(dmaBuf.pWdDma);
}
```

Notice the difference between `ref WD_DMA wdDma` and `IntPtr pWdDma`. The former is used by C# user functions, while the latter is used by WDC API C functions, that can only take a pointer, not a reference.

What Should You Implement?

In the code sample above, it is up to you to implement the following `MyDMAxxx`() routines, according to your device's specification:

- `MyDMAProgram`(): Program the device's DMA registers.
  Refer the device's data sheet for the details.

- `MyDMAStart`(): Write to the device to initiate DMA transfers.

- `MyDMAInterruptEnable`() and `MyDMAInterruptDisable`(): Use `WDC_IntEnable`() [B.3.48] and `WDC_IntDisable`() [B.3.49] (respectively) to enable/disable the software interrupts and write/read the relevant register(s) on the device in order to physically enable/disable the hardware DMA interrupts (see Section 9.2 for details regarding interrupt handling with WinDriver.)

- `MyDMAWaitForCompletion`(): Poll the device for completion or wait for "DMA DONE" interrupt.

- `MyDmaIntHandler`: The device's interrupt handler. `IntHandler` is a pointer to a function prototype of your choice.

When using the basic `WD_xxx` API (described in the **WinDriver PCI Low-Level API Reference**) to allocate a Scatter/Gather DMA buffer that is larger than 1MB, you need to set the `DMA_LARGE_BUFFER` flag in the call to `WD_DMALock`() and allocate memory for the additional memory pages, as explained in the following FAQ: https://www.jungo.com/st/support/windriver/windriver_faqs/#dma1. However, when using `WDC_DMASGBufLock`() [B.3.41] to allocate the DMA buffer, you do not need any special implementation for allocating large buffers, since the function handles this for you.

9.1.2. Implementing Contiguous-Buffer DMA

Following is a sample routine that uses WinDriver's WDC API [B.2] to allocate a contiguous DMA buffer and perform bus-master DMA transfers.
For more detailed, hardware-specific, contiguous DMA examples, refer to the following enhanced-support chipset [7] sample library files:

- PLX — **WinDriver/plx/lib/plx_lib.c** and **WinDriver/plx/diag_lib/plx_diag_lib.c** (which utilizes the **plx_lib.c** DMA API)

- Xilinx Bus Master DMA (BMD) design — **WinDriver/xilinx/bmd_design/bmd_lib.c**

C Example:

```
BOOL DMARoutine(WDC_DEVICE_HANDLE hDev, DWORD dwDMABufSize,
    UINT32 u32LocalAddr, BOOL fPolling, BOOL fToDev)
{
    PVOID pBuf = NULL;
    WD_DMA *pDma = NULL;
    BOOL fRet = FALSE;

    /* Allocate a DMA buffer and open DMA for the selected channel */
    if (!DMAOpen(hDev, &pBuf, u32LocalAddr, dwDMABufSize, fToDev, &pDma))
        goto Exit;
```

```
    /* Enable DMA interrupts (if not polling) */
    if (!fPolling)
    {
        if (!MyDMAInterruptEnable(hDev, MyDmaIntHandler, pDma))
            goto Exit; /* Failed enabling DMA interrupts */
    }

    /* Flush the CPU caches (see documentation of WDC_DMASyncCpu()) */
    WDC_DMASyncCpu(pDma);

    /* Start DMA - write to the device to initiate the DMA transfer */
    MyDMAStart(hDev, pDma);

    /* Wait for the DMA transfer to complete */
    MyDMAWaitForCompletion(hDev, pDma, fPolling);

    /* Flush the I/O caches (see documentation of WDC_DMASyncIo()) */
    WDC_DMASyncIo(pDma);

    fRet = TRUE;

Exit:
    DMAClose(hDev, pDma, fPolling);
    return fRet;
}

/* DMAOpen: Allocates and locks a contiguous DMA buffer */
BOOL DMAOpen(WDC_DEVICE_HANDLE hDev, PVOID *ppBuf, UINT32 u32LocalAddr,
    DWORD dwDMABufSize, BOOL fToDev, WD_DMA **ppDma)
{
    DWORD dwStatus;
    DWORD dwOptions = fToDev ? DMA_TO_DEVICE : DMA_FROM_DEVICE;

    /* Allocate and lock a contiguous DMA buffer */
    dwStatus = WDC_DMAContigBufLock(hDev, ppBuf, dwOptions, dwDMABufSize, ppDma);
    if (WD_STATUS_SUCCESS != dwStatus)
    {
        printf("Failed locking a contiguous DMA buffer. Error 0x%lx - %s\n",
            dwStatus, Stat2Str(dwStatus));
        return FALSE;
    }

    /* Program the device's DMA registers for the physical DMA page */
    MyDMAProgram((*ppDma)->Page, (*ppDma)->dwPages, fToDev, u32LocalAddr);

    return TRUE;
}

/* DMAClose: Frees a previously allocated contiguous DMA buffer */
void DMAClose(WDC_DEVICE_HANDLE hDev, WD_DMA *pDma, BOOL fPolling)
{
    /* Disable DMA interrupts (if not polling) */
    if (!fPolling)
        MyDMAInterruptDisable(hDev);

    /* Unlock and free the DMA buffer */
    WDC_DMABufUnlock(pDma);
}
```

C# Example

```
bool DMARoutine(PCI_Device dev, DWORD dwDMABufSize, UINT32 u32LocalAddr,
    bool fPolling, bool fToDev, IntHandler MyDmaIntHandler)
{
    bool fRet = false;
    IntPtr pBuf = IntPtr.Zero;
    Log log = new Log(new Log.TRACE_LOG(TraceLog),
        new Log.ERR_LOG(ErrLog));
    WD_DMA wdDma = new WD_DMA();
    DmaBuffer dmaBuf = new DmaBufferContig(dev, log);

    /* Lock the DMA buffer and program the DMA controller */
    if (!DMAOpen(ref dmaBuf, pBuf, u32LocalAddr, dwDMABufSize,
        fToDev, ref wdDma))
    {
        fRet = false;
        goto Exit;
    }

    /* Enable DMA interrupts (if not polling) */
    if (!fPolling)
    {
        if (!MyDMAInterruptEnable(dev, MyDmaIntHandler, ref wdDma))
        {
            fRet = false;
            goto Exit;  /* Failed enabling DMA interrupts */
        }
    }

    /* Flush the CPU caches (see documentation of WDC_DMASyncCpu()) */
    wdc_lib_decl.WDC_DMASyncCpu(dmaBuf.pWdDma);

    /* Start DMA - write to the device to initiate the DMA transfer */
    MyDmaStart(dev, ref wdDma);

    /* Wait for the DMA transfer to complete */
    MyDMAWaitForCompletion(dev, ref wdDma, fPolling);

    /* Flush the I/O caches (see documentation of WDC_DMASyncIo()) */
    wdc_lib_decl.WDC_DMASyncIo(dmaBuf.pWdDma);

    fRet = true;

Exit:
    DMAClose(dev, dmaBuf, fPolling);
    return fRet;
}

/* OpenDMA: Locks a Contiguous DMA buffer */
public bool DMAOpen(ref DmaBuffer dmaBuf, IntPtr pBuf, UINT32 u32LocalAddr,
    DWORD bufSize, bool fToDev, ref WD_DMA wdDma)
{
    IntPtr pDma = dmaBuf.pWdDma;
    WDC_DEVICE_HANDLE hDev = dmaBuf.DeviceHandle;
    DWORD dwOptions = fToDev ? (DWORD)WD_DMA_OPTIONS.DMA_TO_DEVICE :
        (DWORD)WD_DMA_OPTIONS.DMA_FROM_DEVICE;
```

```
    wdDma = MarshalDMA(pDma);

    /* Lock a Scatter/Gather DMA buffer */
    if (wdc_lib_decl.WDC_DMAContigBufLock(hDev, ref pBuf, dwOptions,
        bufSize, ref pDma) != (DWORD)wdc_err.WD_STATUS_SUCCESS)
        return false;

    /* Program the device's DMA registers for each physical page */
    MyDMAProgram(fToDev, wdDma.Page[0], wdDma.dwPages, u32LocalAddr);
    return true;
}

/* DMAClose: Unlocks a previously locked Scatter/Gather DMA buffer */
public void DMAClose(PCI_Device dev, DmaBuffer dmaBuf, bool fPolling)
{
    /* Disable DMA interrupts (if not polling) */
    if (!fPolling)
        MyDMAInterruptDisable(dev);

    /* Unlock and free the DMA buffer */
    wdc_lib_decl.WDC_DMABufUnlock(dmaBuf.pWdDma);
}
```

What Should You Implement?

In the code sample above, it is up to you to implement the following `MyDMAxxx()` routines, according to your device's specification:

- `MyDMAProgram()`: Program the device's DMA registers.
  Refer the device's data sheet for the details.

- `MyDMAStart()`: Write to the device to initiate DMA transfers.

- `MyDMAInterruptEnable()` and `MyDMAInterruptDisable()`: Use `WDC_IntEnable()` [B.3.48] and `WDC_IntDisable()` [B.3.49] (respectively) to enable/disable the software interrupts and write/read the relevant register(s) on the device in order to physically enable/disable the hardware DMA interrupts (see Section 9.2 for details regarding interrupt handling with WinDriver.)

- `MyDMAWaitForCompletion()`: Poll the device for completion or wait for "DMA DONE" interrupt.

- `MyDmaIntHandler`: The device's interrupt handler. `IntHandler` is a pointer to a function prototype of your choice.

9.1.2.1. Preallocating Contiguous DMA Buffers on Windows

WinDriver doesn't limit the size of the DMA buffer that can be allocated using its DMA APIs. However, the success of the DMA allocation is dependent on the amount of available system resources at the time of the allocation. Therefore, the earlier you try to allocate the buffer, the better your chances of succeeding.
WinDriver for Windows allows you to configure your device INF file to preallocate contiguous DMA buffers at boot time, thus increasing the odds that the allocation(s) will succeed.

You may preallocate a maximum of 512 buffers: — 256 host-to-device buffers and/or 256 device-to-host buffers.

There are 2 ways to preallocate contiguous DMA buffers on Windows: Directly from the DriverWizard, or manually via editing the INF file.

Directly from DriverWizard:

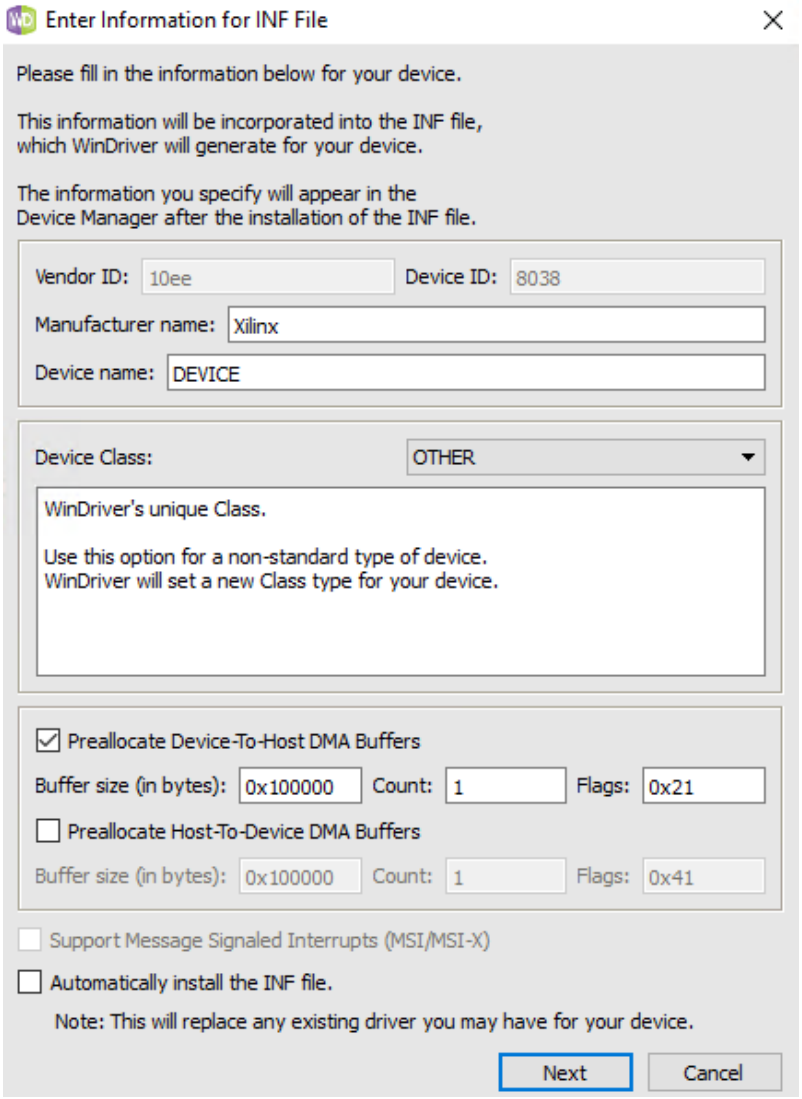
1. In DriverWizard, start a new project, select a device from the list and click **`Generate .INF file`** as shown in the DriverWizard Walkthrough Step 2.

2. Check **`Preallocate Host-To-Device DMA Buffers`** and/or **`Preallocate Device-To-Host DMA Buffers`** to enable the text boxes under each checkbox.

3. Adjust the **`Size, Count`** and **`Flags`** parameters as desired.

The **`Size`** and **`Flags`** fields must be hexadecimal numbers, formatted with the "0x" prefix, as shown below.

Figure 9.1. DriverWizard INF File Information



The supported WinDriver DMA flags are documented in the description of dwOptions field of the `WD_DMA` struct [B.7.9]. To locate the relevant flag values to set in the INF file, look for the flag definitions in the **WinDriver\include\windrvr.h** file; (look for the enum that contains the `DMA_KERNEL_BUFFER_ALLOC` flag).

4. Click **`Next`**, you will then be prompted to choose a filename for your .INF file. After choosing a filename, the INF file will be created and ready to use, with your desired parameters.

Manually by editing an existing INF file:

1. Add the required configuration under the **`[UpdateRegistryDevice]`** registry key in your device INF file, as shown below.

- The examples are for configuring preallocation of eight DMA buffers but you may, of-course, select to preallocate just one buffer (or none at all).

- To preallocate unidirectional buffers, add these lines:

```
; Host-to-device DMA buffer:
HKR,, "DmaToDeviceCount",0x00010001,0x04       ; Number of preallocated
                                               ; DMA_TO_DEVICE buffers
HKR,, "DmaToDeviceBytes",0x00010001,0x100000   ; Buffer size, in bytes
HKR,, "DmaToDeviceOptions",0x00010001,0x41     ; DMA flags (0x40=DMA_TO_DEVICE
                                               ; + 0x1=DMA_KERNEL_BUFFER_ALLOC
; Device-to-host DMA buffer:
HKR,, "DmaFromDeviceCount",0x00010001,0x04     ; Number of preallocated
                                               ; DMA_FROM_DEVICE buffers
HKR,, "DmaFromDeviceBytes",0x00010001,0x100000 ; Buffer size, in bytes
HKR,, "DmaFromDeviceOptions",0x00010001,0x21   ; DMA flags (0x20=DMA_FROM_DEVICE
                                               ; + 0x1=DMA_KERNEL_BUFFER_ALLOC)
```

2. Edit the buffer sizes and add flags to the options masks in the INF file, as needed. Note, however, that the direction flags and the `DMA_KERNEL_BUFFER_ALLOC` flag must be set as shown in Step 1.

The supported WinDriver DMA flags are documented in the description of dwOptions field of the `WD_DMA` struct [B.7.9]. To locate the relevant flag values to set in the INF file, look for the flag definitions in the **WinDriver\include\windrvr.h** file; (look for the enum that contains the `DMA_KERNEL_BUFFER_ALLOC` flag).

3. In your code, the first **n** calls (if you configured the INF file to preallocate **n** DMA buffers) to the contiguous-DMA-lock function — `WDC_DMAContigBufLock()` [B.3.40] — should set parameter values that match the buffer configurations in the INF file:

   - For a **device-to-host** buffer, the DMA-options mask parameter (**`dwOptions / pDma->dwOptions`**) should contain the same DMA flags set in the **`DmaFromDeviceOptions`** registry key value, and the buffer-size parameter (**`dwDMABufSize / pDma->dwBytes`**) should be set to the value of the **`DmaFromDeviceBytes`** registry key value.

   - For a **host-to-device** buffer, the DMA-options mask parameter (**`dwOptions / pDma->dwOptions`**) should contain the same flags set in the **`DmaToDeviceOptions`** registry key value, and the buffer-size parameter (**`dwDMABufSize / pDma->dwBytes`**) should be set to the value of the **`DmaToDeviceBytes`** registry key value.

- When using `WDC_DMAContigBufLock()` [B.3.40] you don't need to explicitly set the `DMA_KERNEL_BUFFER_ALLOC` flag (which must be set in the INF-file configuration) because the function sets this flag automatically.
- When using the low-level WinDriver `WD_DMALock()` function (described in the **WinDriver PCI Low-Level API Reference**), the DMA options are set in the function's `pDma->dwOptions` parameter — which must also include the `DMA_KERNEL_BUFFER_ALLOC` flag — and the buffer size is set in the `pDma->dwBytes` parameter.
- If the buffer preallocation fails due to insufficient resources, you may need to increase the size of the non-paged pool (from which the memory is allocated), as explained in WinDriver Technical Document 58 (https://www.jungo.com/st/support/tech_docs/td58.html).

9.2. Handling Interrupts

WinDriver provides you with API, DriverWizard code generation, and samples, to simplify the task of handling interrupts from your driver.

If you are developing a driver for a device based on one of the enhanced-support WinDriver chipsets [7], we recommend that you use the custom WinDriver interrupt APIs for your specific chip in order to handle the interrupts, since these routines are implemented specifically for the target hardware.

For other chips, we recommend that you use DriverWizard to detect/define the relevant information regarding the device interrupt (such as the interrupt request (IRQ) number, its type and its shared state), define commands to be executed in the kernel when an interrupt occurs (if required), and then generate skeletal diagnostics code, which includes interrupt routines that demonstrate how to use WinDriver's API to handle your device's interrupts, based on the information that you defined in the wizard.

The following sections provide a general overview of PCI/ISA interrupt handling and explain how to handle interrupts using WinDriver's API. Use this information to understand the sample and generated DriverWizard interrupt code or to write your own interrupt handler.

9.2.1. Interrupt Handling — Overview

PCI and ISA hardware uses interrupts to signal the host.
There are two main methods of PCI interrupt handling:

- **Legacy Interrupts:** The traditional interrupt handling, which uses a line-based mechanism. In this method, interrupts are signaled by using one or more external pins that are wired "out-of-band", i.e., separately from the main bus lines.

Legacy interrupts are divided into two groups:

- **Level-sensitive interrupts:** These interrupts are generated as long as the physical interrupt signal is high. If the interrupt signal is not lowered by the end of the interrupt handling in the kernel, the operating system will call the kernel interrupt handler repeatedly, causing the host platform to hang. To prevent such a situation, the interrupt must be acknowledged (cleared) by the kernel interrupt handler immediately when it is received.

  Legacy PCI interrupts are level sensitive.

- **Edge-triggered interrupts:** These are interrupts that are generated once, when the physical interrupt signal goes from low to high. Therefore, exactly one interrupt is generated. No special action is required for acknowledging this type of interrupt.

  ISA/EISA interrupts are edge triggered.

- **MSI/MSI-X:** Newer PCI bus technologies, available beginning with v2.2 of the PCI bus and in PCI Express, support Message-Signaled Interrupts (**MSI**). This method uses "in-band" messages instead of pins, and can target addresses in the host bridge. A PCI function can request up to 32 MSI messages.
  Note: MSI and MSI-X are edge triggered and do not require acknowledgment in the kernel.

  Among the advantages of MSIs:

  - MSIs can send data along with the interrupt message.

  - As opposed to legacy PCI interrupts, MSIs are not shared; i.e., an MSI that is assigned to a device is guaranteed to be unique within the system.

  Extended Message-Signaled Interrupts (**MSI-X**) are available beginning with version 3.0 of the PCI bus. This method provides an enhanced version of the MSI mechanism, which includes the following advantages:

  - Supports 2,048 messages instead of 32 messages supported by the standard MSI.

  - Supports independent message address and message data for each message.

  - Supports per-message masking.

  - Enables more flexibility when software allocates fewer vectors than hardware requests. The software can reuse the same MSI-X address and data in multiple MSI-X slots.

  The newer PCI buses, which support MSI/MSI-X, maintain software compatibility with the legacy line-based interrupts mechanism by emulating legacy interrupts through in-band mechanisms. These emulated interrupts are treated as legacy interrupts by the host operating system.

WinDriver supports legacy line-based interrupts, both edge triggered and level sensitive, on all supported operating systems: Windows, and Linux.

WinDriver also supports PCI MSI/MSI-X interrupts (when supported by the hardware) on Linux and Windows 7 and higher (earlier versions of Windows do not support MSI/MSI-X), as detailed in Section 9.2.7.

WinDriver provides a single set of APIs for handling both legacy and MSI/MSI-X interrupts, as described in this manual.

9.2.2. WinDriver Interrupt Handling Sequence

This section describes how to use WinDriver to handle interrupts from a user-mode application. Since interrupt handling is a performance-critical task, it is very likely that you may want to handle the interrupts directly in the kernel. WinDriver's Kernel PlugIn [11] enables you to implement kernel-mode interrupt routines.
To find out how to handle interrupts from the Kernel PlugIn, please refer to Section 11.6.5 of the manual.

The interrupt handling sequence using WinDriver is as follows:

1. The user calls one of WinDriver's interrupt enable functions — `WDC_IntEnable`() [B.3.48] or the low-level `InterruptEnable`() or `WD_IntEnable`() functions, described in the **WinDriver PCI Low-Level API Reference** — to enable interrupts on the device.
   These functions receive an optional array of read/write transfer commands to be executed in the kernel when an interrupt occurs (see Step 3).

   NOTE:

   - When using WinDriver to handle level-sensitive interrupts, you **must** set up transfer commands for acknowledging the interrupt, as explained in Section 9.2.6.

   - Memory allocated for the transfer commands must remain available until the interrupts are disabled .

   When `WDC_IntEnable`() [B.3.48] or the lower-level `InterruptEnable`() function is called, WinDriver spawns a thread for handling incoming interrupts.
   When using the low-level `WD_IntEnable`() function you need to spawn the thread yourself.

   WinDriver must be registered with the OS as the driver of the device before enabling interrupts. For Plug-and-Play hardware (PCI/PCI Express) on Windows platforms, this association is made by installing an INF file for the device [15.1]. If the INF file is not installed, `the interrupt enable function`() will fail with a `WD_NO_DEVICE_OBJECT` error [B.11].

2. The interrupt thread runs an infinite loop that waits for an interrupt to occur.

3. When an interrupt occurs, WinDriver executes, in the kernel, any transfer commands that were prepared in advance by the user and passed to WinDriver's interrupt-enable functions (see Section 9.2.6).

When the control returns to the user mode, the driver's user-mode interrupt handler routine (as passed to WinDriver when enabling the interrupts with `WDC_IntEnable`() or `InterruptEnable`()) is called.

4. When the user-mode interrupt handler returns, the wait loop continues.

5. When the user no longer needs to handle interrupts, or before the user-mode application exits, the relevant WinDriver interrupt disable function should be called — `WDC_IntDisable`() [B.3.49] or the low-level `InterruptDisable`() or `WD_IntDisable`() functions, described in the **WinDriver PCI Low-Level API Reference** (depending on the function used to enable the interrupts).

- The low-level `WD_IntWait`() WinDriver function (described in the **WinDriver PCI Low-Level API Reference**), which is used by the high-level interrupt enable functions to wait on interrupts from the device, puts the thread to sleep until an interrupt occurs. **There is no CPU consumption while waiting for an interrupt.** Once an interrupt occurs, it is first handled by the WinDriver kernel, then `WD_IntWait`() wakes up the interrupt handler thread and returns, as explained above.

- Since your interrupt handler runs in the user mode, you may call any OS API from this function, including file-handling and GDI functions.

9.2.3. Registering IRQs for Non-Plug-and-Play Hardware on Windows 7 and Higher

On Windows 7 and higher, you may need to register an interrupt request (IRQ) with WinDriver before you can assign it to your non-Plug-and-Play device (e.g., your ISA card).
To register an IRQ with WinDriver on Windows, follow these steps:

1. Open the Device Manager and select **View --> Resources by type**.

2. Select a free IRQ from among those listed in the *Interrupt request (IRQ)* section.

3. Register the selected IRQ with WinDriver:

   a. Back up the files in the **WinDriver\redist** directory.

   b. Edit **windrvr1281.inf**:

      i. Add the following line in the `[DriverInstall.NT]` section:
      ```
      LogConfig=config_irq
      ```

      ii. Add a `config_irq` section (where "**<IRQ>**" signifies your selected IRQ number — e.g., 10):
      ```
      [config_irq]
      IRQConfig=<IRQ>
      ```

c. Reinstall WinDriver by running the following from a command-line prompt (where "**<path to windrvr1281.inf>**" is the path to your modified WinDriver INF file):
```
wdreg -inf <path to windrvr1281.inf> install
```

d. Verify that that the IRQ was successfully registered with WinDriver: Open the Device Manager and locate the WinDriver device. The device properties should have a **Resources** tab with the registered IRQ.

This procedure registers the IRQ with the virtual WinDriver device. It is recommended that you rename the **windrvr1281** driver module, to avoid possible conflicts with other instances of WinDriver that may be running on the same machine [15.2].
If you rename your driver, replace references to **windrvr1281.inf** in the IRQ registration instructions above with the name of your renamed WinDriver INF file.

9.2.4. Determining the Interrupt Types Supported by the Hardware

When retrieving resources information for a Plug-and-Play device using `WDC_PciGetDeviceInfo()` [B.3.16] or the low-level `WD_PciGetCardInfo()` function (described in the **WinDriver PCI Low-Level API Reference**), the function returns information regarding the interrupt types supported by the hardware. This information is returned within the **`dwOptions`** field of the returned interrupt resource (`pDeviceInfo->Card.Item[i].I.Int.dwOptions` for the WDC functions `pPciCard->Card.Item[i].I.Int.dwOptions` for the low-level functions). The interrupt options bit-mask can contain a combination of any of the following interrupt type flags:

- **`INTERRUPT_MESSAGE_X`**: Extended Message-Signaled Interrupts (MSI-X).*
- **`INTERRUPT_MESSAGE`**: Message-Signaled Interrupts (MSI).*
- **`INTERRUPT_LEVEL_SENSITIVE`**: Legacy level-sensitive interrupts.
- **`INTERRUPT_LATCHED`**: Legacy edge-triggered interrupts. The value of this flag is zero and it is applicable only when no other interrupt flag is set.

The **`WDC_GET_INT_OPTIONS`** macro returns a WDC device's interrupt options bit-mask [B.4.9]. You can pass the returned bit-mask to the **`WDC_INT_IS_MSI`** macro to check whether the bit-mask contains the MSI or MSI-X flags [B.4.10].

- The **`INTERRUPT_MESSAGE`** and **`INTERRUPT_MESSAGE_X`** flags are applicable only to PCI devices [9.2.7].
- * The Windows APIs do not distinguish between MSI and MSI-X; therefore, on this OS the WinDriver functions set the **`INTERRUPT_MESSAGE`** flag for both MSI and MSI-X.

9.2.5. Determining the Interrupt Type Enabled for a PCI Card

When attempting to enable interrupts for a PCI card on Linux or Windows 7 and higher, WinDriver first tries to use MSI-X or MSI, if supported by the card. If this fails, WinDriver attempts to enable legacy level-sensitive interrupts.
WinDriver's interrupt-enable functions return information regarding the interrupt type that was enabled for the card. This information is returned within the **`dwEnabledIntType`** field of the `WD_INTERRUPT` structure that was passed to the function. When using the high-level `WDC_IntEnable`() function, the information is stored within the `Int` field of the WDC device structure referred to by the function's `hDev` parameter [B.3.48], and can be retrieved using the **`WDC_GET_ENABLED_INT_TYPE`** low-level WDC macro [B.4.8].

9.2.6. Setting Up Kernel-Mode Interrupt Transfer Commands

When handling interrupts you may find the need to perform high-priority tasks at the kernel-mode level immediately when an interrupt occurs. For example, when handling level-sensitive interrupts, such as legacy PCI interrupts [9.2.1], the interrupt line **must** be lowered (i.e., the interrupt must be acknowledged) in the kernel, otherwise the operating system will repeatedly call WinDriver's kernel interrupt handler, causing the host platform to hang. Acknowledgment of the interrupt is hardware-specific and typically involves writing or reading from specific runtime registers on the device.

WinDriver's interrupt enable functions receive an optional pointer to an array of `WD_TRANSFER` structures [B.7.10], which can be used to set up read/write transfer command from/to memory or I/O addresses on the device.
The `WDC_IntEnable`() function [B.3.48] accepts this pointer and the number of commands in the array as direct parameters (`pTransCmds` and `dwNumCmds`).
The low-level `InterruptEnable`() and `WD_IntEnable`() functions receive this information within the `Cmd` and `dwCmds` fields of the `WD_INTERRUPT` structure that is passed to them (see the **WinDriver PCI Low-Level API Reference**).

When you need to execute performance-critical transfers to/from your device upon receiving an interrupt — e.g., when handling level-sensitive interrupts — you should prepare an array of `WD_TRANSFER` structures that contain the required information regarding the read/write operations to perform in the kernel upon arrival of an interrupt, and pass this array to WinDriver's interrupt enable functions. As explained in Section 9.2.2, Step 3, WinDriver's kernel-mode interrupt handler will execute the transfer commands passed to it within the interrupt enable function for each interrupt that it handles, before returning the control to the user mode. Note: Memory allocated for the transfer commands must remain available until the interrupts are disabled .

9.2.6.1. Interrupt Mask Commands

The interrupt transfer commands array that you pass to WinDriver can also contain an interrupt mask structure, which will be used to verify the source of the interrupt. This is done by setting the transfer structure's `cmdTrans` field, which defines the type of the transfer command, to **`CMD_MASK`**, and setting the relevant mask in the transfer structure's `Data` field [B.7.10]. Note that interrupt mask commands must be set directly after a read transfer command in the transfer commands array.

When WinDriver's kernel interrupt handler encounters a mask interrupt command, it masks the value that was read from the device in the preceding read transfer command in the array, with the mask set in the interrupt mask command. If the mask is successful, WinDriver will claim control of the interrupt, execute the rest of the transfer commands in the array, and invoke your user-mode interrupt handler routine when the control returns to the user mode. However, if the mask fails, WinDriver will reject control of the interrupt, the rest of the interrupt transfer commands will not be executed, and your user-mode interrupt handler routine will not be invoked. (Note: acceptance and rejection of the interrupt is relevant only when handling legacy interrupts; since MSI/MSI-X interrupts are not shared, WinDriver will always accept control of such interrupts.)

- To correctly handle shared PCI interrupts, you must always include a mask command in your interrupt transfer commands array, and set up this mask to check whether the interrupt handler should claim ownership of the interrupt.
- Ownership of the interrupt will be determined according to the result of this mask. If the mask fails, no other transfer commands from the transfer commands array will be executed — including commands that preceded the mask command in the array. If the mask succeeds, WinDriver will proceed to perform any commands that precede the first mask command (and its related read command) in the transfer commands array, and then any commands that follow the mask command in the array.
- To gain more flexibility and control over the interrupt handling, you can use WinDriver's Kernel PlugIn feature, which enables you to write your own kernel-mode interrupt handler routines, as explained in Section 11.6.5 of the manual.

9.2.6.2. Sample WinDriver Transfer Commands Code

This section provides sample code for setting up interrupt transfer commands using the WinDriver Card (WDC) library API [B.2].
The sample code is provided for the following scenario: Assume you have a PCI card that generates level-sensitive interrupts. When an interrupt occurs you expect the value of your card's interrupt command-status register (`INTCSR`), which is mapped to an I/O port address (`pAddr`), to be `intrMask`.
In order to clear and acknowledge the interrupt you need to write 0 to the `INTCSR`.

The code below demonstrates how to define an array of transfer commands that instructs WinDriver's kernel-mode interrupt handler to do the following:

1. Read your card's `INTCSR` register and save its value.

2. Mask the read `INTCSR` value against the given mask (`intrMask`) to verify the source of the interrupt.

3. If the mask was successful, write 0 to the `INTCSR` to acknowledge the interrupt.

Note: all commands in the example are performed in modes of DWORD.

Example

```
WD_TRANSFER trans[3]; /* Array of 3 WinDriver transfer command structures */
BZERO(trans);

/* 1st command: Read a DWORD from the INTCSR I/O port */
trans[0].cmdTrans = RP_DWORD;
/* Set address of IO port to read from: */
trans[0].pPort = pAddr; /* Assume pAddr holds the address of the INTCSR */

/* 2nd command: Mask the interrupt to verify its source */
trans[1].cmdTrans = CMD_MASK;
trans[1].Data.Dword = intrMask; /* Assume intrMask holds your interrupt mask */

/* 3rd command: Write DWORD to the INTCSR I/O port.
   This command will only be executed if the value read from INTCSR in the
   1st command matches the interrupt mask set in the 2nd command. */
trans[2].cmdTrans = WP_DWORD;
/* Set the address of IO port to write to: */
trans[2].pPort = pAddr; /* Assume pAddr holds the address of INTCSR */
/* Set the data to write to the INTCSR IO port: */
trans[2].Data.Dword = 0;
```

After defining the transfer commands, you can proceed to enable the interrupts.
Note that memory allocated for the transfer commands must remain available until the interrupts are disabled , as explained above.
The following code demonstrates how to use the `WDC_IntEnable`() function to enable the interrupts using the transfer commands prepared above:

```
/* Enable the interrupts:
   hDev: WDC_DEVICE_HANDLE received from a previous call to WDC_PciDeviceOpen().
   INTERRUPT_CMD_COPY: Used to save the read data - see WDC_IntEnable().
   interrupt_handler: Your user-mode interrupt handler routine.
   pData: The data to pass to the interrupt handler routine. */
WDC_IntEnable(hDev, &trans, 3, INTERRUPT_CMD_COPY, interrupt_handler,
    pData, FALSE);
```

9.2.7. WinDriver MSI/MSI-X Interrupt Handling

As indicated in Section 9.2.1, WinDriver supports PCI Message-Signaled Interrupts (MSI) and Extended Message-Signaled Interrupts (MSI-X) on Linux and Windows 7 and higher (earlier versions of Windows do not support MSI/MSI-X).

The same APIs are used for handling both legacy and MSI/MSI-X interrupts, including APIs for retrieving the interrupt types supported by your hardware [9.2.4] and the interrupt type that was enabled for it [9.2.5].

When enabling interrupts for a PCI device on an OS that supports MSI/MSIx, WinDriver first tries to enable MSI-X or MSI — if supported by the device — and if this fails, it attempts to enable legacy level-sensitive interrupts.

On **Windows**, enabling MSI or MSIx interrupts requires that a relevant INF file first be installed for the device, as explained in Section 9.2.7.1.

On **Linux**, you can specify the types of PCI interrupts that may be enabled for your device, via the **dwOptions** parameter of the `WDC_IntEnable`() function [B.3.48] or of the low-level `InterruptEnable`() function (described in the **WinDriver PCI Low-Level API Reference**) — in which case WinDriver will only attempt to enable interrupts of the specified types (provided they are supported by the device).

WinDriver's kernel-mode interrupt handler sets the interrupt message data in the **`dwLastMessage`** field of the `WD_INTERRUPT` structure that was passed to the interrupt enable/wait function. If you pass the same interrupt structure as part of the data to your user-mode interrupt handler routine, as demonstrated in the sample and generated DriverWizard interrupt code, you will be able to access this information from your interrupt handler.
When using a Kernel PlugIn driver [11], the last message data is passed to your kernel-mode `KP_IntAtDpcMSI` [B.8.11] handler; on Windows 7 and higher, it is also passed to `KP_IntAtIrqlMSI` [B.8.10].
You can use the low-level **`WDC_GET_ENABLED_INT_LAST_MSG`** macro to retrieve the last message data for a given WDC device [B.4.11].

9.2.7.1. Windows MSI/MSI-X Device INF Files

The information in this section is relevant only when working on Windows.

To successfully handle PCI interrupts with WinDriver on Windows, you must first install an INF file that registers your PCI card to work with WinDriver's kernel driver, as explained in Section 15.1.

To use MSI/MSI-X on Windows, the card's INF file must contain specific `[Install.NT.HW]` MSI information, as demonstrated below:

```
[Install.NT.HW]
AddReg = Install.NT.HW.AddReg

[Install.NT.HW.AddReg]
HKR, "Interrupt Management", 0x00000010
HKR, "Interrupt Management\MessageSignaledInterruptProperties", 0x00000010
HKR, "Interrupt Management\MessageSignaledInterruptProperties", MSISupported, \
    0x10001, 1
```

Therefore, to use MSI/MSI-X on Windows 7 and higher with WinDriver — provided your hardware supports MSI/MSI-X — you need to install an appropriate INF file.

When using DriverWizard on Windows 7 and higher to generate an INF file for a PCI device that supports MSI/MSI-X, the INF generation dialogue allows you to select to generate an INF file that supports MSI/MSI-X (see Section 4.2, Step 3).

In addition, the WinDriver sample code for the Xilinx Bus Master DMA (BMD) design, which demonstrates MSI handling, includes a sample MSI INF file for this design — **WinDriver/xilinx/bmd_design/xilinx_bmd.inf**.

If your card's INF file does not include MSI/MSI-X information, as detailed above, WinDriver will attempt to handle your card's interrupts using the legacy level-sensitive interrupt handling method, even if your hardware supports MSI/MSI-X.

9.2.8. Sample User-Mode WinDriver Interrupt Handling Code

The sample code below demonstrates how you can use the WDC library's [B.2] interrupt APIs (described in Sections B.3.48–B.3.50 of the manual) to implement a simple user-mode interrupt handler.
For complete interrupt handler source code that uses the WDC interrupt functions, refer, for example, to the WinDriver **pci_diag** (**WinDriver/samples/pci_diag**) and PLX (**WinDriver/plx**) samples, and to the generated DriverWizard PCI/ISA code. For a sample of MSI interrupt handling, using the same APIs, refer to the Xilinx Bus Master DMA (BMD) design sample (**WinDriver/xilinx/bmd_design**), or to the code generated by DriverWizard for PCI hardware that supports MSI/MSI-X on the supported operating systems (Linux or Windows 7 and higher).

- The following sample code demonstrates interrupt handling for an edge-triggered ISA card. The code does not set up any kernel-mode interrupt transfer commands [9.2.6], which is acceptable in the case of edge-triggered or MSI/MSI-X interrupts [9.2.1]. Note that when using WinDriver to handle level-sensitive interrupts from the user mode, you must set up transfer commands for acknowledging the interrupt in the kernel, as explained above and as demonstrated in Section 9.2.6.

- As mentioned above [9.2.7], WinDriver provides a single set of APIs for handling both legacy and MSI/MSI-X interrupts. You can therefore also use the following code to handle MSI/MSI-X PCI interrupts (if supported by your hardware), on Linux or Windows 7 and higher, by simply replacing the use of `WDC_IsaDeviceOpen`() in the sample with `WDC_PciDeviceOpen`() [B.3.17].

```
VOID DLLCALLCONV interrupt_handler (PVOID pData)
{
    PWDC_DEVICE pDev = (PWDC_DEVICE)pData;

    /* Implement your interrupt handler routine here */

    printf("Got interrupt %d\n", pDev->Int.dwCounter);
}

...

int main()
{
    DWORD dwStatus;
    WDC_DEVICE_HANDLE hDev;
    ...
```

```
WDC_DriverOpen(WDC_DRV_OPEN_DEFAULT, NULL);
...

hDev = WDC_IsaDeviceOpen(...);
...
/* Enable interrupts. This sample passes the WDC device handle as the data
    for the interrupt handler routine */
dwStatus = WDC_IntEnable(hDev, NULL, 0, 0,
    interrupt_handler, (PVOID)hDev, FALSE);
/* WDC_IntEnable() allocates and initializes the required WD_INTERRUPT
    structure, stores it in the WDC_DEVICE structure, then calls
    InterruptEnable(), which calls WD_IntEnable() and creates an interrupt
    handler thread. */
if (WD_STATUS_SUCCESS != dwStatus)
{
   printf ("Failed enabling interrupt. Error: 0x%x - %s\n",
       dwStatus, Stat2Str(dwStatus));
}
else
{
    printf("Press Enter to uninstall interrupt\n");
    fgets(line, sizeof(line), stdin);

    WDC_IntDisable(hDev);
    /* WDC_IntDisable() calls InterruptDisable();
       InterruptDisable() calls WD_IntDisable(). */
}
```

```
    ...
    WDC_IsaDeviceClose(hDev);
    ...
    WDC_DriverClose();
}
```

9.3. Buffer sharing between multiple processes

This section describes how to share a contiguous DMA buffer or a kernel buffer between multiple processes.
The buffer sharing mechanism can be used to improve the work of multiple processes by allowing the developer avoiding unnecessary buffer copying.
Coupled with the WinDriver IPC mechanism it might also be used as a way for two processes to convey large messages/data.

Currently WinDriver supports sharing DMA contiguous buffer (See `WDC_DMAContigBufLock`() [B.3.40]) and Kernel buffer (See `WDS_SharedBufferAlloc`() [B.6.1]).

In order to share a buffer the developer must first pass its global handle to the other process(es). See Macros `WDS_SharedBufferGetGlobalHandle`() [B.6.4] and `WDC_DMAGetGlobalHandle`() [B.3.45] for getting a buffer's global handle.
Than, the handle should be passed to the other process(es). E.g. by WinDriver IPC calls: `WDS_IpcUidUnicast`() [C.2.8], `WDS_IpcSubGroupMulticast`() [C.2.7] or `WDS_IpcMulticast`() [C.2.6].

After a process gets the global buffer handle, it should use `WDC_DMABufGet`() [B.3.44] or `WDS_SharedBufferGet`() [B.6.3] to retrieve the buffer. WinDriver will re-map the buffer to the new process virtual memory (I.e. user-space) and will fill all the necessary information as though the buffer was allocated from the calling process.

Once the process no longer needs the shared buffer it should use the regular unlock/free calls - `WDC_DMABufUnlock`() [B.3.43], `WDS_SharedBufferFree`() [B.6.2] appropriately.

WinDriver manages all system resources, hence the call to `WDC_DMABufUnlock`() [B.3.43], `WDS_SharedBufferFree`() [B.6.2] will not remove system resources until all processes no longer use the buffer.

Chapter 10
Improving Performance

10.1. Overview

Once your user-mode driver has been written and debugged, you might find that certain modules in your code do not operate fast enough (for example: an interrupt handler or accessing I/O-mapped regions). If this is the case, try to improve performance in one of the following ways:

- Improve the performance of your user-mode driver [10.2].
- Create a Kernel PlugIn driver [11] and move the performance-critical portions of your code to the Kernel PlugIn.

Use the following checklist to determine how to best improve the performance of your driver.

10.1.1. Performance Improvement Checklist

The following checklist will help you determine how to improve the performance of your driver:

Problem	Solution
ISA Card — accessing an I/O-mapped range on the card	When transferring a large amount of data, use block (string) transfers and/or group several data transfer function calls into a single multi-transfer function call, as explained in Section 10.2.2 below. If this does not solve the problem, handle the I/O at kernel mode by writing a Kernel PlugIn driver, as explained in Chapters 11 and 12 of the manual.
PCI Card — accessing an I/O-mapped range on the card	Avoid using I/O ranges in your hardware design. Use Memory mapped ranges instead as they are accessed significantly faster.
Accessing a memory-mapped range on the card	Try to access memory directly instead of using function calls, as explained in Section 10.2.1 below. When transferring large amounts of data, consider also the solution to problem #1 above. If the problem persists, then there is a hardware design problem. You will not be able to increase performance by using any software design method, writing a Kernel PlugIn, or even by writing a full kernel driver.
Interrupt latency — missing interrupts, receiving interrupts too late	Handle the interrupts in the kernel mode by writing a Kernel PlugIn driver, as explained in Chapters 11 and 12.
PCI target access vs. master access	PCI target access is usually slower than PCI master access (bus-master DMA). For large data transfers, bus-master DMA access is preferable. Section 9.1 of the manual explains how to use WinDriver to implement bus-master DMA.

10.2. Improving the Performance of a User-Mode Driver

As a general rule, transfers to memory-mapped regions are faster than transfers to I/O-mapped regions, because WinDriver enables you to access memory-mapped regions directly from the user mode, without the need for a function call, as explained in Section 10.2.1.

In addition, the WinDriver APIs enable you to improve the performance of your I/O and memory data transfers by using block (string) transfers and by grouping several data transfers into a single function call, as explained in Section 10.2.2.

10.2.1. Using Direct Access to Memory-Mapped Regions

When registering a PCI card, using `WDC_xxxDeviceOpen`() (PCI [B.3.17] / ISA [B.3.18]) or the low-level `WD_CardRegister`() function (see the **WinDriver PCI Low-Level API Reference**), WinDriver returns both user-mode and kernel-mode mappings of the card's physical memory regions. These addresses can then be used to access the memory regions on the card directly, either from the user mode or from the kernel mode (respectively), thus eliminating the context switches between the user and kernel modes and the function calls overhead for accessing the memory.

The `WDC_MEM_DIRECT_ADDR` macro [B.4.4] provides the relevant direct memory access base address — user-mode mapping when called from the user-mode / kernel-mode mapping when called from a Kernel PlugIn driver [11] — for a given memory address region on the card. You can then pass the mapped base address to the `WDC_ReadMem8/16/32/64` [B.3.24] and `WDC_WriteMem8/16/32/64` [B.3.25] macros, along with the desired offset within the selected memory region, to directly access a specific memory address on the card, either from the user mode or in the kernel.
In addition, all the `WDC_ReadAddrXXX`() [B.3.26] and `WDC_WriteAddrXXX`() [B.3.27] functions — with the exception of `WDC_ReadAddrBlock`() [B.3.28] and `WDC_WriteAddrBlock`() [B.3.29] — access memory addresses directly, using the correct mapping, based on the calling context (user mode/kernel mode).

When using the low-level `WD_xxx`() APIs, described in the **WinDriver PCI Low-Level API Reference**, the user-mode and kernel-mode mappings of the card's physical memory regions are returned by `WD_CardRegister`() within the `pTransAddr` and `pUserDirectAddr` fields of the `pCardReg->Card.Item[i]` card resource item structures. The `pTransAddr` result should be used as a base address in calls to `WD_Transfer`()or `WD_MultiTransfer`() or when accessing memory directly from a Kernel PlugIn driver [11]. To access the memory directly from your user-mode process, use `pUserDirectAddr` as a regular pointer.

Whatever the method you select to access the memory on your card, it is important to align the base address according to the size of the data type, especially when issuing string transfer commands. Otherwise, the transfers are split into smaller portions.
The easiest way to align data is to use basic types when defining a buffer, i.e.:

```
BYTE buf[len];      /* for BYTE transfers - not aligned */
WORD buf[len];      /* for WORD transfers - aligned on a 2-byte boundary */
UINT32 buf[len];    /* for DWORD transfers - aligned on a 4-byte boundary */
UINT64 buf[len];    /* for QWORD transfers - aligned on a 8-byte boundary */
```

10.2.2. Block Transfers and Grouping Multiple Transfers

To transfer large amounts of data to/from memory addresses or I/O addresses (which by definition cannot be accessed directly, as opposed to memory addresses — see Section 10.2.1), use the following methods to improve performance by reducing the function calls overhead and context switches between the user and kernel modes:

- Perform block (string) transfers using `WDC_ReadAddrBlock`() [B.3.28] / `WDC_WriteAddrBlock`() [B.3.29], or the low-level `WD_Transfer`() function (see **WinDriver PCI Low-Level API Reference**).

- Group several transfers into a single function call, using `WDC_MultiTransfer`() [B.3.30] or the low-level `WD_MultiTransfer`() function (see the **WinDriver PCI Low-Level API Reference**).

10.2.3. Performing 64-Bit Data Transfers

The ability to perform actual 64-bit transfers is dependent on the existence of support for such transfers by the hardware, CPU, bridge, etc., and can be affected by any of these factors or their specific combination.

WinDriver supports 64-bit PCI data transfers on the supported Windows and Linux 64-bit platforms (see Appendix A for a full list), as well as on Windows and Linux 32-bit x86 platforms.

If your PCI hardware (card and bus) is 64-bit, the ability to perform 64-bit data transfers on 32-bit platforms will enable you to utilize your hardware's broader bandwidth, even if your host operating system is only 32-bit.

This innovative technology makes possible data transfer rates previously unattainable on 32-bit platforms. Drivers developed using WinDriver will attain significantly better performance results than drivers written with the WDK or other driver development tools. To date, such tools do not enable 64-bit data transfer on x86 platforms running 32-bit operating systems. Jungo's benchmark performance testing results for 64-bit data transfer indicate a significant improvement of data transfer rates compared to 32-bit data transfer, guaranteeing that drivers developed with WinDriver will achieve far better performance than 32-bit data transfer normally allows.

You can perform 64-bit data transfers using any of the following methods:

- Call `WDC_ReadAddr64`() [B.3.26] or `WDC_WriteAddr64`() [B.3.27].
- Call `WDC_ReadAddrBlock`() [B.3.28] or `WDC_WriteAddrBlock`() [B.3.29] with an access mode of `WDC_SIZE_64` [B.3.1.4].
- Call `WDC_MultiTransfer`() [B.3.30] or the low-level `WD_Transfer`() or `WD_MultiTransfer`() functions (see **WinDriver PCI Low-Level API Reference**) with QWORD read/write transfer commands (see the documentation of these functions for details).

You can also perform 64-bit transfers to/from the PCI configuration space using `WDC_PciReadCfg64`() [B.3.38] / `WDC_PciWriteCfg64`() [B.3.39] and `WDC_PciReadCfgBySlot64`() [B.3.36] / `WDC_PciWriteCfgBySlot64`() [B.3.37].

Chapter 11
Understanding the Kernel PlugIn

This chapter provides a description of WinDriver's Kernel PlugIn feature.

11.1. Background

The creation of drivers in user mode imposes a fair amount of function call overhead from the kernel to user mode, which may cause performance to drop to an unacceptable level. In such cases, the Kernel PlugIn feature allows critical sections of the driver code to be moved to the kernel while keeping most of the code intact. Using WinDriver's Kernel PlugIn feature, your driver will operate without any degradation in performance.

Writing a Kernel PlugIn driver provides the following advantages over a standard OS kernel-mode driver:

- All the driver code is written and debugged in the user mode.
- The code segments that are moved to the kernel mode remain essentially the same, and therefore typically no kernel debugging is needed.
- The parts of the code that will run in the kernel through the Kernel PlugIn are platform-independent, and therefore will run on every platform supported by WinDriver and the Kernel PlugIn. A standard kernel-mode driver will run only on the platform it was written for.

Using WinDriver's Kernel PlugIn feature, your driver will operate without any performance degradation.

11.2. Do I Need to Write a Kernel PlugIn Driver?

Not every performance problem requires you to write a Kernel PlugIn driver. Some performance problems can be solved in the user-mode driver by better utilization of the features that WinDriver provides. For further information, please refer to Chapter 10.

11.3. What Kind of Performance Can I Expect?

Since you can write your own interrupt handler in the kernel with the WinDriver Kernel PlugIn, you can expect to handle about 100,000 interrupts per second without missing any one of them.

11.4. Overview of the Development Process

Using the WinDriver Kernel PlugIn, you normally first develop and debugs the driver in the user mode, using with the standard WinDriver tools. After identifying the performance-critical parts of the code (such as the interrupt handling or access to I/O-mapped memory ranges), you can create a Kernel PlugIn driver, which runs in kernel mode, and drop the performance-critical portions of your code into the Kernel PlugIn driver, thus eliminating the calling overhead and context switches that occur when implementing the same tasks in the user mode.

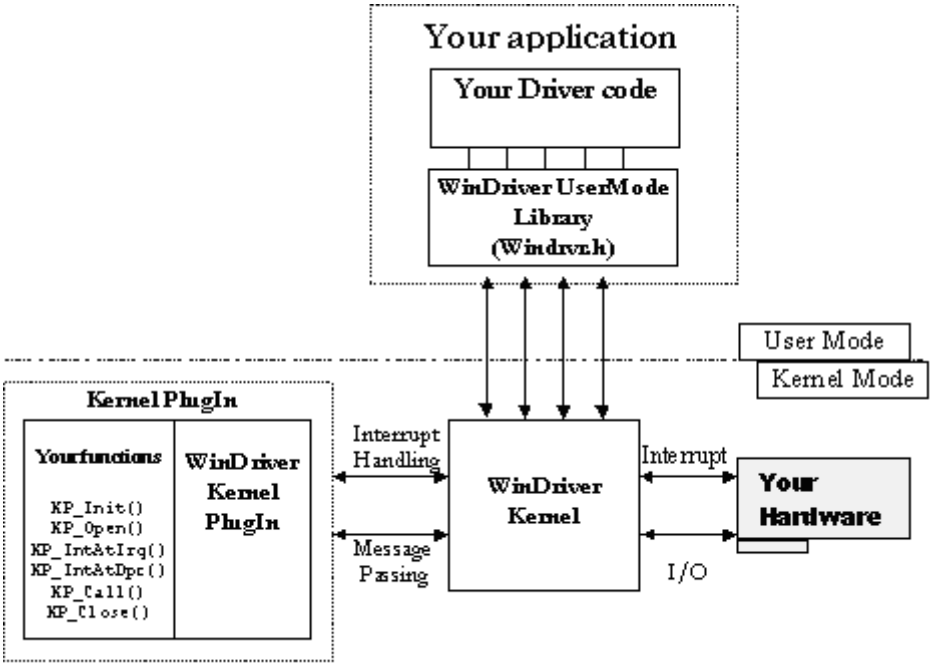
This unique architecture allows the developer to start with quick and easy development in the user mode, and progress to performance-oriented code only where needed, thus saving development time and providing for virtually zero performance degradation.

11.5. The Kernel PlugIn Architecture

11.5.1. Architecture Overview

A driver written in user mode uses WinDriver's API (`WDC_xxx` and/or `WD_xxx` [B.2]) to access devices. If a certain function that was implemented in the user mode requires kernel performance (the interrupt handler, for example), that function is moved to the WinDriver Kernel PlugIn. Generally it should be possible to move code that uses `WDC_xxx / WD_xxx` function calls from the user mode to the kernel without modification, since the same WinDriver API is supported both in the user mode and in the Kernel PlugIn.

Figure 11.1. Kernel PlugIn Architecture



11.5.2. WinDriver's Kernel and Kernel PlugIn Interaction

There are two types of interaction between the WinDriver kernel and the WinDriver Kernel PlugIn:

- **Interrupt handling:** When WinDriver receives an interrupt, by default it will activate the caller's user-mode interrupt handler. However, if the interrupt was set to be handled by a Kernel PlugIn driver, then once WinDriver receives the interrupt, it activates the Kernel PlugIn driver's kernel-mode interrupt handler. Your Kernel PlugIn interrupt handler could essentially consist of the same code that you wrote and debugged in the user-mode interrupt handler, before moving to the Kernel PlugIn, although some of the user-mode code should be modified. We recommend that you rewrite the interrupt acknowledgment and handling code in the Kernel PlugIn to utilize the flexibility offered by the Kernel PlugIn (see Section 11.6.5).

- **Message passing:** To execute functions in kernel mode (such as I/O processing functions), the user-mode driver simply passes a message to the WinDriver Kernel PlugIn. The message is mapped to a specific function, which is then executed in the kernel. This function can typically contain the same code as it did when it was written and debugged in user mode.
  You can also use messages to pass data from the user-mode application to the Kernel PlugIn driver.

11.5.3. Kernel PlugIn Components

At the end of your Kernel PlugIn development cycle, your driver will have the following components:

- User-mode driver application (**<application name>/.exe**), written with the `WDC_xxx / WD_xxx` API.
- The WinDriver kernel module — **windrvr1281.sys/.o/.ko**, depending on the operating system.
- Kernel PlugIn driver (**<Kernel PlugIn driver name>/.sys/.o/.ko/.kext**), which was also written with the `WDC_xxx / WD_xxx` API, and contains the driver functionality that you have selected to bring down to the kernel level.

11.5.4. Kernel PlugIn Event Sequence

The following is a typical event sequence that covers all the functions that you can implement in your Kernel PlugIn:

11.5.4.1. Opening a Handle from the User Mode to a Kernel PlugIn Driver

Event/Callback	Notes
Event: Windows loads your Kernel PlugIn driver.	This takes place at boot time, by dynamic loading, or as instructed by the registry.
Callback: Your `KP_Init` Kernel PlugIn routine [B.8.1] is called	`KP_Init` informs WinDriver of the name(s) of your `KP_Open` routine(s) [B.8.2]. WinDriver calls the relevant open routine when there is a user-mode request to open a handle to your Kernel PlugIn driver.
Event: Your user-mode driver application requests a handle to your Kernel PlugIn driver, by calling one of the following functions: • `WDC_KernelPlugInOpen`() [B.3.22] • `WDC_xxxDeviceOpen`() (PCI [B.3.17] / ISA [B.3.18]) with the name of the Kernel PlugIn driver • `WD_KernelPlugInOpen`() — when using the low-level WinDriver API (see the **WinDriver PCI Low-Level API Reference**)	
Callback: The relevant `KP_Open` Kernel PlugIn callback routine [B.8.2] is called.	The `KP_Open` [B.8.2] callback is used to inform WinDriver of the names of all the callback functions that you have implemented in your Kernel PlugIn driver, and to initiate the Kernel PlugIn driver, if needed.

11.5.4.2. Handling User-Mode Requests from the Kernel PlugIn

Event/Callback	Notes
Event: Your application calls `WDC_CallKerPlug()` [B.3.23], or the low-level `WD_KernelPlugInCall()` function (see the **WinDriver PCI Low-Level API Reference**).	Your application calls `WDC_CallKerPlug()` / `WD_KernelPlugInCall()` to execute code in the kernel mode (in the Kernel PlugIn driver). The application passes a message to the Kernel PlugIn driver. The Kernel PlugIn driver will select the code to execute according to the message sent.
Callback: Your `KP_Call` Kernel PlugIn routine [B.8.4] is called.	`KP_Call` [B.8.4] executes code according to the message passed to it from the user mode.

11.5.4.3. Interrupt Handling — Enable/Disable and High Interrupt Request Level Processing

Event/Callback	Notes
Event: Your application calls `WDC_IntEnable`() [B.3.48] with the `fUseKP` parameter set to `TRUE` (after having opened a handle to the Kernel PlugIn), or calls the low-level `InterruptEnable`() or `WD_IntEnable`() functions (see the **WinDriver PCI Low-Level API Reference**) with a handle to a Kernel PlugIn driver (set in the `hKernelPlugIn` field of the `WD_INTERRUPT` structure passed to the function).	
Callback: Your `KP_IntEnable` Kernel PlugIn routine [B.8.6] is called.	This function should contain any initialization required for your Kernel PlugIn interrupt handling.
Event: Your hardware creates an interrupt.	
Callback: Your high-IRQL Kernel PlugIn interrupt handler routine — `KP_IntAtIrql` [B.8.8] (legacy interrupts) or `KP_IntAtIrqlMSI` [B.8.10] (MSI/MSI-X) — is called.	`KP_IntAtIrql` [B.8.8] and `KP_IntAtIrqlMSI` [B.8.10] run at a high priority, and therefore should perform only the basic interrupt handling, such as lowering the HW interrupt signal of level-sensitive interrupts to acknowledge the interrupt. If more interrupt processing is required, `KP_IntAtIrql` (legacy interrupts) or `KP_IntAtIrqlMSI` (MSI/MSI-X) can return `TRUE` in order to defer additional processing to the relevant deferred processing interrupt handler — `KP_IntAtDpc` [B.8.9] or `KP_IntAtDpcMSI` [B.8.11].
Event: Your application calls `WDC_IntDisable`() [B.3.49], or the low-level `InterruptDisable`() or `WD_IntDisable`() functions (see the **WinDriver PCI Low-Level API Reference**), when the interrupts were previously enabled in the Kernel PlugIn (see the description of the interrupt enable event above).	
Callback: Your `KP_IntDisable` Kernel PlugIn routine [B.8.7] is called.	This function should free any memory that was allocated by the `KP_IntEnable` callback [B.8.6].

11.5.4.4. Interrupt Handling — Deferred Procedure Calls

Event/Callback	Notes
Event: The Kernel PlugIn high-IRQL interrupt handler — `KP_IntAtIrql` [B.8.8] or `KP_IntAtIrqlMSI` [B.8.10] — returns `TRUE`.	This informs WinDriver that additional interrupt processing is required as a Deferred Procedure Call (DPC) in the kernel.
Callback: Your Kernel PlugIn DPC interrupt handler — `KP_IntAtDpc` [B.8.9] (legacy interrupts) or `KP_IntAtDpcMSI` [B.8.11] (MSI/MSI-X) — is called.	Processes the rest of the interrupt code, but at a lower priority than the high-IRQL interrupt handler.
Event: The DPC interrupt handler — `KP_IntAtDpc` [B.8.9] or `KP_IntAtDpcMSI` [B.8.11] — returns a value greater than 0.	This informs WinDriver that additional user-mode interrupt processing is required.
Callback: `WD_IntWait`() (see the **WinDriver PCI Low-Level API Reference**) returns.	Your user-mode interrupt handler routine is executed.

11.5.4.5. Plug-and-Play and Power Management Events

Event/Callback	Notes
Event: Your application registers to receive Plug-and-Play and power management notifications using a Kernel PlugIn driver, by calling `WDC_EventRegister()` [B.3.52] with the with the `fUseKP` parameter set to `TRUE` (after having opened the device with a Kernel PlugIn), or calls the low-level `EventRegister()` (see the **WinDriver PCI Low-Level API Reference**) or `WD_EventRegister()` functions with a handle to a Kernel PlugIn driver (set in the `hKernelPlugIn` field of the `WD_EVENT` structure that is passed to the function).	
Event: A Plug-and-Play or power management event (to which the application registered to listen) occurs.	
Callback: Your `KP_Event` Kernel PlugIn routine [B.8.5] is called.	`KP_Event` receives information about the event that occurred and can proceed to handle it as needed.
Event: `KP_Event` [B.8.5] returns `TRUE`.	This informs WinDriver that the event also requires user-mode handling.
Callback: `WD_IntWait()` (see the **WinDriver PCI Low-Level API Reference**) returns.	Your user-mode event handler routine is executed.

11.6. How Does Kernel PlugIn Work?

The following sections take you through the development cycle of a Kernel PlugIn driver.

It is recommended that you first write and debug your entire driver code in the user mode. Then, if you encounter performance problems or require greater flexibility, port portions of your code to a Kernel PlugIn driver.

11.6.1. Minimal Requirements for Creating a Kernel PlugIn Driver

To build a Kernel PlugIn driver you need the following tools:

- On Windows: The Windows Driver Kit (WDK), including its C build tools.

The WDK is available as part of a Microsoft Development Network (MSDN) subscription, or from Microsoft Connect. For more information, refer to Microsoft's Windows Driver Kit (WDK) page — https://msdn.microsoft.com/en-us/library/windows/hardware/gg487428.aspx.

- On **Linux**:
  - **GCC**, **gmake** or **make**

While this is not a minimal requirement, when developing a Kernel PlugIn driver it is highly recommended that you use two computers: set up one computer as your host platform and the other as your target platform. The host computer is the computer on which you develop your driver and the target computer is the computer on which you run and test the driver you develop.

11.6.2. Kernel PlugIn Implementation

11.6.2.1. Before You Begin

The functions described in this section are callback functions, implemented in the Kernel PlugIn driver, which are called when their calling event occurs — see Section 11.5.4 for details. For example, `KP_Init` [B.8.1] is the callback function that is called when the driver is loaded.

The name of your driver is given in `KP_Init`. The Kernel PlugIn driver's implementation of this callback must be named `KP_Init`. The names of the other Kernel PlugIn callback functions (which are passed to `KP_Init`) are left to the discretion of the driver developer. It is the convention of this reference guide to refer to these callbacks using the format `KP_<Functionality>` — for example, `KP_Open`.
When generating Kernel PlugIn code with the DriverWizard, the names of the callback functions (apart from `KP_Init`) conform to the following format: **KP_<Driver Name>_<Functionality>**. For example, if you named your project **MyDevice**, the name of your Kernel PlugIn `KP_Call` callback will be `KP_MyDevice_Call`.

11.6.2.2. Write Your KP_Init Function

Your `KP_Init` function [B.8.1] should be of the following prototype:

```
BOOL __cdecl KP_Init (KP_INIT *kpInit);
```

This function is called once, when the driver is loaded. The function should fill the received `KP_INIT` structure [B.9.4] with the name of the Kernel PlugIn driver, the name of the WinDriver Kernel PlugIn driver library, and the driver's `KP_Open` callback(s) [B.8.2] (see example in **WinDriver/samples/pci_diag/kp_pci/kp_pci.c**).

- The name that you select for your Kernel PlugIn driver — by setting it in the `cDriverName` field of the `KP_INIT` structure [B.9.4] that is passed to `KP_Init` [B.8.1] — should be the name of the driver that you wish to create; i.e., if you are creating a driver called **XXX.sys**, you should set the name "XXX" in the `cDriverName` field of the `KP_INIT` structure.

- You should verify that the driver name that is used when opening a handle to the Kernel PlugIn driver in the user mode [12.5] — in the `pKPOpenData` parameter of the `WDC_KernelPlugInOpen`() [B.3.22] or `WDC_xxxDeviceOpen`() (PCI [B.3.17] / ISA [B.3.18]) functions, or in the `pcDriverName` field of the `pKernelPlugIn` parameter passed to the low-level `WD_KernelPlugInOpen`() function — is identical to the driver name that was set in the `cDriverName` field of the `KP_INIT` structure [B.9.4] that is passed to `KP_Init` [B.8.1].
  The best way to implement this is to define the driver name in a header file that is shared by the user-mode application and the Kernel PlugIn driver and use the defined value in all relevant locations.

From the **KP_PCI** sample (**WinDriver/samples/pci_diag/kp_pci/kp_pci.c**):

```
/* KP_Init is called when the Kernel PlugIn driver is loaded.
   This function sets the name of the Kernel PlugIn driver and the driver's
   open callback function(s). */
BOOL __cdecl KP_Init(KP_INIT *kpInit)
{
    /* Verify that the version of the WinDriver Kernel PlugIn library
        is identical to that of the windrvr.h and wd_kp.h files */
    if (WD_VER != kpInit->dwVerWD)
    {
        /* Rebuild your Kernel PlugIn driver project with the compatible
           version of the WinDriver Kernel PlugIn library (kp_nt<version>.lib)
           and windrvr.h and wd_kp.h files */
        return FALSE;
    }

    kpInit->funcOpen = KP_PCI_Open;
    kpInit->funcOpen_32_64 = KP_PCI_VIRT_Open_32_64;
    strcpy (kpInit->cDriverName, KP_PCI_DRIVER_NAME);

    return TRUE;
}
```

Note that the driver name in the sample is set using a preprocessor definition. This definition is found in the **WinDriver/samples/pci_diag/pci_lib.h** header file, which is shared by the **pci_diag** user-mode application and the **KP_PCI** Kernel PlugIn driver:

```
/* Kernel PlugIn driver name (should be no more than 8 characters) */
#define KP_PCI_DRIVER_NAME "KP_PCI"
```

11.6.2.3. Write Your KP_Open Function(s)

You can implement either one or two `KP_Open` functions, depending on your target configuration [B.8.2]. The `KP_Open` function(s) should be of the following prototype:

```
BOOL __cdecl KP_Open (
    KP_OPEN_CALL *kpOpenCall,
    HANDLE hWD,
    PVOID pOpenData,
    PVOID *ppDrvContext);
```

This callback is called when opening a handle to the Kernel PlugIn driver from the user mode — i.e., when `WD_KernelPlugInOpen`() is called, either directly or via `WDC_KernelPlugInOpen`() [B.3.22] or `WDC_xxxDeviceOpen`() (PCI [B.3.17] / ISA [B.3.18]), as explained in Section 12.5.

In the `KP_Open` function, define the callbacks that you wish to implement in the Kernel PlugIn.

The following is a list of the callbacks that can be implemented:

Callback	Functionality
`KP_Close` [B.8.3]	Called when the `WD_KernelPlugInClose`() function (see the **WinDriver PCI Low-Level API Reference**) is called from the user mode — either directly, or via one of the high-level `WDC_xxxDeviceClose`() functions (PCI [B.3.19] / ISA [B.3.20]) when called for a device that contains an open Kernel PlugIn handle [12.5].
`KP_Call` [B.8.4]	Called when the user-mode application calls the `WDC_CallKerPlug`() function [B.3.23] or the low-level `WD_KernelPlugInCall`() function (see the **WinDriver PCI Low-Level API Reference**), which is called by the wrapper `WDC_CallKerPlug`() function. This function implements a Kernel PlugIn message handler.

Callback	Functionality
KP_IntEnable [B.8.6]	Called when the user-mode application enables Kernel PlugIn interrupts, by calling WDC_IntEnable() with the fUseKP parameter set to TRUE (after having opened a Kernel PlugIn handle), or by calling the low-level InterruptEnable() or WD_IntEnable() functions (see the **WinDriver PCI Low-Level API Reference**) with a handle to a Kernel PlugIn driver (set in the hKernelPlugIn field of the WD_INTERRUPT structure that is passed to the function). This function should contain any initialization required for your Kernel PlugIn interrupt handling.
KP_IntDisable [B.8.7]	Called when the user-mode application calls WDC_IntDisable() [B.3.49], or the low-level InterruptDisable() or WD_IntDisable() functions (see the **WinDriver PCI Low-Level API Reference**), if the interrupts were previously enabled with a Kernel PlugIn driver (see the description of KP_IntEnable above). This function should free any memory that was allocated by the KP_IntEnable callback [B.8.6].
KP_IntAtIrql [B.8.8]	Called when WinDriver receives a legacy interrupt, provided the received interrupt was enabled with a handle to the Kernel PlugIn. This is the function that will handle your legacy interrupt in the kernel mode. The function runs at high interrupt request level. Additional deferred processing of the interrupt can be performed in KP_IntAtDpc and also in the user mode (see below).

Callback	Functionality
`KP_IntAtDpc` [B.8.9]	Called if the `KP_IntAtIrql` callback [B.8.8] has requested deferred handling of a legacy interrupt by returning `TRUE`. This function should include lower-priority kernel-mode interrupt handler code. The return value of this function determines the amount of times that the application's user-mode interrupt handler routine will be invoked (if at all).
`KP_IntAtIrqlMSI` [B.8.10]	Called when WinDriver receives an MSI or MSI-X, provided MSI/MSI-X was enabled for the received interrupt with a handle to the Kernel PlugIn. This is the function that will handle your MSI/MSI-X in the kernel mode. The function runs at high interrupt request level. Additional deferred processing of the interrupt can be performed in `KP_IntAtDpcMSI` and also in the user mode (see below). Note: MSI/MSI-X is supported on Linux and Windows 7 and higher.
`KP_IntAtDpcMSI` [B.8.11]	Called if the `KP_IntAtIrqlMSI` callback [B.8.10] has requested deferred handling of an MSI/MSI-X interrupt by returning `TRUE`. This function should include lower-priority kernel-mode MSI/MSI-X handler code. The return value of this function determines the amount of times that the application's user-mode interrupt handler routine will be invoked (if at all). Note: MSI/MSI-X is supported on Linux and Windows 7 and higher.

Callback	Functionality
KP_Event [B.8.5]	Called when a Plug-and-Play or power management event occurs, provided the user-mode application previously registered to receive notifications for this event in the Kernel PlugIn by calling WDC_EventRegister() [B.3.52] with the fUseKP parameter set to TRUE (after having opened a Kernel PlugIn handle), or by calling the low-level EventRegister() (see the **WinDriver PCI Low-Level API Reference**) or WD_EventRegister() functions with a handle to a Kernel PlugIn driver (set in the hKernelPlugIn field of the WD_EVENT structure that is passed to the function).

As indicated above, these handlers will be called (respectively) when the user-mode program opens/closes a handle to Kernel PlugIn driver [12.5], sends a message to the Kernel PlugIn driver (by calling WDC_CallKerPlug() / WD_KernelPlugInCall()), enables interrupts with a Kernel PlugIn driver (by calling WDC_IntEnable() with the fUseKP parameter set to TRUE, after having opened a handle to the Kernel PlugIn / calling InterruptEnable() or WD_InterruptEnable() with a handle to the Kernel PlugIn set in the hKernelPlugIn field of the WD_INTERRUPT structure that is passed to function), or disables interrupts (WDC_IntDisable()/ InterruptDisable() / WD_IntDisable()) that have been enabled using a Kernel PlugIn driver;
The Kernel PlugIn interrupt handlers will be called when an interrupt occurs, if the interrupts were enabled using a Kernel PlugIn driver (see above).
The Kernel PlugIn event handler will be called when a Plug-and-Play or power management event occurs, if the application registered to receive notifications for the event that occurred using a Kernel PlugIn driver (by calling WDC_EventRegister() with the fUseKP parameter set to TRUE, after having opened the device with a Kernel PlugIn / calling EventRegister() (see the **WinDriver PCI Low-Level API Reference**) or WD_EventRegister() with a handle to a Kernel PlugIn driver set in the hKernelPlugIn field of the WD_EVENT structure that is passed to the function).

In addition to defining the Kernel PlugIn callback functions, you can implement code to perform any required initialization for the Kernel PlugIn in your KP_Open callback(s) [B.8.2]. In the sample **KP_PCI** driver and in the generated DriverWizard Kernel PlugIn driver, for example, the Kernel PlugIn open callbacks also call the shared library's initialization function and allocate memory for the Kernel PlugIn driver context, which is then used to store the device information that was passed to the function from the user mode.

From the **KP_PCI** sample (**WinDriver/samples/pci_diag/kp_pci/kp_pci.c**):

```
/* KP_PCI_Open is called when WD_KernelPlugInOpen() is called from the
   user mode.
   pDrvContext will be passed to the rest of the Kernel PlugIn callback
   functions. */
BOOL __cdecl KP_PCI_Open(KP_OPEN_CALL *kpOpenCall, HANDLE hWD, PVOID pOpenData,
    PVOID *ppDrvContext)
{
    PCI_DEV_ADDR_DESC *pDevAddrDesc;
    WDC_ADDR_DESC *pAddrDesc;
    DWORD dwSize;
    DWORD dwStatus;

    /* Initialize the PCI library */
    dwStatus = PCI_LibInit();
    if (WD_STATUS_SUCCESS != dwStatus)
    {
        KP_PCI_Err("KP_PCI_Open: Failed to initialize the PCI library: %s",
            PCI_GetLastErr());
        return FALSE;
    }

    KP_PCI_Trace("KP_PCI_Open entered. PCI library initialized.\n");

    kpOpenCall->funcClose = KP_PCI_Close;
    kpOpenCall->funcCall = KP_PCI_Call;
    kpOpenCall->funcIntEnable = KP_PCI_IntEnable;
    kpOpenCall->funcIntDisable = KP_PCI_IntDisable;
    kpOpenCall->funcIntAtIrql = KP_PCI_IntAtIrql;
    kpOpenCall->funcIntAtDpc = KP_PCI_IntAtDpc;
    kpOpenCall->funcIntAtIrqlMSI = KP_PCI_IntAtIrqlMSI;
    kpOpenCall->funcIntAtDpcMSI = KP_PCI_IntAtDpcMSI;
    kpOpenCall->funcEvent = KP_PCI_Event;

    /* Create a copy of device information in the driver context */
    dwSize = sizeof(PCI_DEV_ADDR_DESC);
    pDevAddrDesc = malloc(dwSize);
    if (!pDevAddrDesc)
        goto malloc_error;

    COPY_FROM_USER(pDevAddrDesc, pOpenData, dwSize);
    dwSize = sizeof(WDC_ADDR_DESC) * pDevAddrDesc->dwNumAddrSpaces;
    pAddrDesc = malloc(dwSize);
    if (!pAddrDesc)
        goto malloc_error;

    COPY_FROM_USER(pAddrDesc, pDevAddrDesc->pAddrDesc, dwSize);
    pDevAddrDesc->pAddrDesc = pAddrDesc;
    *ppDrvContext = pDevAddrDesc;

    KP_PCI_Trace("KP_PCI_Open: Kernel PlugIn driver opened successfully\n");

    return TRUE;

malloc_error:
    KP_PCI_Err("KP_PCI_Open: Failed allocating %ld bytes\n", dwSize);
    if (pDevAddrDesc)
        free(pDevAddrDesc);
    PCI_LibUninit();
    return FALSE;
}
```

The **KP_PCI** sample also defines a similar `KP_PCI_Open_32_64` callback, for use when opening a handle to a 64-bit Kernel PlugIn from a 32-bit application.

11.6.2.4. Write the Remaining PlugIn Callbacks

Implement the remaining Kernel PlugIn routines that you wish to use (such as the `KP_Intxxx` functions — for handling interrupts, or `KP_Event` — for handling Plug-and-Play and power management events).

11.6.3. Sample/Generated Kernel PlugIn Driver Code Overview

You can use DriverWizard to generate a skeletal Kernel PlugIn driver for your device, and use the generated code as the basis for your Kernel PlugIn driver development (recommended); alternatively, you can use one of the Kernel PlugIn WinDriver samples as the basis for your Kernel PlugIn development.

The Kernel PlugIn documentation in this manual focuses on the generated DriverWizard code, and the generic PCI Kernel PlugIn sample — **KP_PCI**, located in the **WinDriver/samples/pci_diag/kp_pci** directory.
If you are using the a PCI Express card with the Xilinx Bus Master DMA (BMD) design, you can also use the **KP_BMD** Kernel PlugIn sample as the basis for your development; the **WinDriver/xilinx/bmd_design** directory contains all the relevant sample files — see the Xilinx BMD Kernel PlugIn directory structure note at the end of Section 11.6.4.1.

The Kernel PlugIn driver is not a standalone module. It requires a user-mode application that initiates the communication with the driver. A relevant application will be generated for your driver when using DriverWizard to generate Kernel PlugIn code. The **pci_diag** application (found under the **WinDriver/samples/pci_diag** directory) communicates with the sample **KP_PCI** driver.

Both the **KP_PCI** sample and the wizard-generated code demonstrate communication between a user-mode application (**pci_diag** / **xxx_diag** — where **xxx** is the name you selected for your generated driver project) and a Kernel PlugIn driver (**kp_pci.sys/.o/.ko/.kext** / **kp_xxx.sys/.o/.ko/.kext** — depending on the OS).

The sample/generated code demonstrates how to pass data to the Kernel PlugIn's `KP_Open` function, and how to use this function to allocate and store a global Kernel PlugIn driver context that can be used by other functions in the Kernel PlugIn.

The sample/generated Kernel PlugIn code implements a message for getting the driver's version number, in order to demonstrate how to initiate specific functionality in the Kernel PlugIn from the user mode and how to pass data between the Kernel PlugIn driver and a user-mode WinDriver application via messages.

The sample/generated code also demonstrates how to handle interrupts in the Kernel PlugIn. The Kernel PlugIn implements an interrupt counter and interrupt handlers, including deferred processing interrupt handling, which is used to notify the user-mode application of the arrival of every fifth incoming interrupt.
The **KP_PCI** sample's `KP_IntAtIrql` [B.8.8] and `KP_IntAtDpc` [B.8.9] functions demonstrate legacy level-sensitive PCI interrupt handling. As indicated in the comments of the sample `KP_IntAtIrql` function, you will need to modify this function in order to implement the correct code for acknowledging the interrupt on your specific device, since interrupt acknowledgment is hardware-specific. The sample `KP_IntAtIrqlMSI` [B.8.10] and `KP_IntAtDpcMSI` [B.8.11] functions demonstrate handling of Message-Signaled Interrupts (MSI) and Extended Message-Signaled Interrupts (MSI-X) (see detailed information in Section 9.2).
The **generated DriverWizard code** will include sample interrupt handler code for the selected device (PCI/ISA). The generated `KP_IntAtIrql` function will include code to implement any interrupt transfer commands defined in the wizard (by assigning registers read/write commands to the card's interrupt in the **Interrupt** tab). For legacy PCI interrupts, which need to be acknowledged in the kernel when the interrupt is received (see Section 9.2), it is recommended that you use the wizard to define the commands for acknowledging (clearing) the interrupt, before generating the Kernel PlugIn code, so that the generated code will already include the required code for executing the commands you defined. It is also recommended that you prepare such transfer commands when handling interrupts for hardware that supports MSI/MSI-X, in case enabling of MSI/MSI-X fails and the interrupt handling defaults to using level-sensitive interrupts (if supported by the hardware).
Note: Memory allocated for the transfer commands must remain available until the interrupts are disabled .

In addition, the sample/generated code demonstrates how to receive notifications of Plug-and-Play and power management events in the Kernel PlugIn.

We recommend that you build and run the sample/generated Kernel PlugIn project (and corresponding user-mode application) "as-is" before modifying the code or writing your own Kernel PlugIn driver. Note, however, that you will need to modify or remove the hardware-specific transfer commands in the sample's `KP_IntAtIrql` function, as explained above.

11.6.4. Kernel PlugIn Sample/Generated Code Directory Structure

11.6.4.1. pci_diag and kp_pci Sample Directories

The **KP_PCI** Kernel PlugIn sample code is implemented in the **kp_pci.c** file. This sample driver is part of the WinDriver PCI diagnostics sample — **pci_diag** — which contains, in addition to the **KP_PCI** driver, a user-mode application that communicates with the driver (**pci_diag**) and a shared library that includes APIs that can be utilized by both the user-mode application and the Kernel PlugIn driver. The source files for this sample are implemented in C.

Following is an outline of the files found in the **WinDriver/samples/pci_diag** directory:

- **kp_pci** — Contains the **KP_PCI** Kernel PlugIn driver files:
  - **kp_pci.c**: The source code of the **KP_PCI** driver.
  - Project and/or make files and related files for building the Kernel PlugIn driver.
    The Windows project/make files are located in subdirectories for the target development environment (**msdev_<version>/win_gcc**) under **x86** (32-bit) and **amd64** (64-bit) directories.
    The Linux makefile is generated using a **configure** script, located directly under the **kp_pci** directory.
  - A pre-compiled version of the **KP_PCI** Kernel PlugIn driver for the target OS:
    - Windows x86 32-bit: **WINNT.i386\kp_pci.sys** — a 32-bit version of the driver, built for Windows 7 and higher.
    - Windows x64: **WINNT.x86_64\kp_pci.sys** — a 64-bit version of the driver, built for Windows Server 2003 and higher.
    - Linux: There is no pre-compiled version of the driver for Linux, since Linux kernel modules must be compiled with the header files from the kernel version installed on the target — see Section 14.3.
- **pci_lib.c**: Implementation of a library for accessing PCI devices using WinDriver's WDC API [B.2]. The library's API is used both by the user-mode application (**pci_diag.c**) and by the Kernel PlugIn driver (**kp_pci.c**).
- **pci_lib.h**: Header file, which provides the interface for the **pci_lib** library.
- **pci_diag.c**: Implementation of a sample diagnostics user-mode console (CUI) application, which demonstrates communication with a PCI device using the **pci_lib** and **WDC** libraries. The sample also demonstrates how to communicate with a Kernel PlugIn driver from a user-mode WinDriver application. By default, the sample attempts to open the selected PCI device with a handle to the **KP_PCI** Kernel PlugIn driver. If successful, the sample demonstrates how to interact with a Kernel PlugIn driver, as detailed in Section 11.6.3. If the application fails to open a handle to the Kernel PlugIn driver, all communication with the device is performed from the user mode.
- **pci.inf** (Windows): A sample WinDriver PCI INF file for Windows. NOTE: To use this file, change the vendor and device IDs in the file to comply with those of your specific device.

To use Message-Signaled Interrupts (MSI) or Extended Message-Signaled Interrupts (MSI-X) on Windows 7 and higher (for PCI cards that support MSI/MSI-X) you will need to modify or replace the sample INF file so that your INF file includes specific MSI information; otherwise WinDriver will attempt to use legacy level-sensitive interrupt handling for your card, as explained in Section 9.2.7.1 of the manual.

- Project and/or make files for building the **pci_diag** user-mode application.
  The Windows project/make files are located in subdirectories for the target development environment (**msdev_<version>/win_gcc**) under **x86** (32-bit) and **amd64** (64-bit) directories. The **msdev_<version>** MS Visual Studio directories also include solution files for building both the Kernel PlugIn driver and user-mode application projects.
  The Linux makefile is located under a **LINUX** subdirectory.

- A pre-compiled version of the user-mode application (**pci_diag**) for your target operating system:

  - Windows: **WIN32\pci_diag.exe**

  - Linux: **LINUX/pci_diag**

- **files.txt**: A list of the sample **pci_diag** files.

- **readme.txt**: An overview of the sample Kernel PlugIn driver and user-mode application and instructions for building and testing the code.

Xilinx BMD Kernel PlugIn Directory Structure
The structure of the sample directory for PCI Express cards with the Xilinx Bus Master DMA (BMD) design — **WinDriver/xilinx/bmd_design** — is similar to that of the generic PCI sample's **pci_diag** directory, except for the following issues: the **bmd_diag** user-mode application files are located under a **diag** subdirectory, and the **kp** subdirectory, which contains the Kernel PlugIn driver's (**KP_BMD**) source files, currently has make files only for Windows.

11.6.4.2. The Generated DriverWizard Kernel PlugIn Directory

The generated DriverWizard Kernel PlugIn code for your device will include a kernel-mode Kernel PlugIn project and a user-mode application that communicates with it. As opposed to the generic **KP_PCI** and **pci_diag** sample, the wizard-generated code will utilize the resources information detected and/or defined for your specific device, as well as any device-specific information that you define in the wizard before generating the code.

As indicated in Section 11.6.3, when using the driver to handle legacy PCI interrupts, it is highly recommended that you define the registers that need to be read/written in order to acknowledge the interrupt, and set up the relevant read/write commands from/to these registers in DriverWizard, before generating the code, thus enabling the generated interrupt handler code to utilize the hardware-specific information that you defined. It is also recommended that you prepare such transfer commands when handling interrupts for hardware that supports MSI/MSI-X, in case enabling of MSI/MSI-X fails and the interrupt handling defaults to using level-sensitive interrupts (if supported by the hardware).
Note: Memory allocated for the transfer commands must remain available until the interrupts are disabled .

Following is an outline of the generated DriverWizard files when selecting to generate Kernel PlugIn code (where **xxx** signifies the name that you selected for the driver when generating the code). NOTE: The outline below relates to the generated C code, but on Windows you can also generate similar C# code, which includes a C Kernel PlugIn driver (since kernel-mode drivers cannot be implemented in C#), a .NET C# library, and a C# user-mode application that communicates with the Kernel PlugIn driver.

- **kermode** — Contains the **KP_XXX** Kernel PlugIn driver files:
  - **kp_xxx.c**: The source code of the **KP_XXX** driver.
  - Project and/or make files and related files for building the Kernel PlugIn driver.
    The Windows project/make files are located in subdirectories for the target development environment (**msdev_<version>/win_gcc**) under **x86** (32-bit) and **amd64** (64-bit) directories.
    The Linux makefile is generated using a **configure** script, located in a **linux** subdirectory.
- **xxx_lib.c**: Implementation of a library for accessing your device using WinDriver's WDC API [B.2]. The library's API is used both by the user-mode application (**xxx_diag**) and by the Kernel PlugIn driver (**KP_XXX**).
- **xxx_lib.h**: Header file, which provides the interface for the **xxx_lib** library.
- **xxx_diag.c**: Implementation of a sample diagnostics user-mode console (CUI) application, which demonstrates communication your device using the **xxx_lib** and **WDC** libraries.
  The application also demonstrates how to communicate with a Kernel PlugIn driver from a user-mode WinDriver application. By default, the application attempts to open your device with a handle to the **KP_XXX** Kernel PlugIn driver. If successful, the application demonstrates how to interact with a Kernel PlugIn driver, as detailed in Section 11.6.3. If the application fails to open a handle to the Kernel PlugIn driver, all communication with the device is performed from the user mode.
- Project and/or make files for building the **xxx_diag** user-mode application.
  The Windows project/make files are located in subdirectories for the target development environment (**msdev_<version>/win_gcc**) under **x86** (32-bit) and **amd64** (64-bit) directories. The **msdev_<version>** MS Visual Studio directories also include solution files for building both the Kernel PlugIn driver and user-mode application projects.
  The Linux makefile is located in a **linux** subdirectory.
- **xxx_files.txt**: A list of the generated files and instructions for building the code.
- **xxx.inf** (Windows): A WinDriver INF file for your device. This file is required only when creating a Windows driver for a Plug-and-Play device, such as PCI.

11.6.5. Handling Interrupts in the Kernel PlugIn

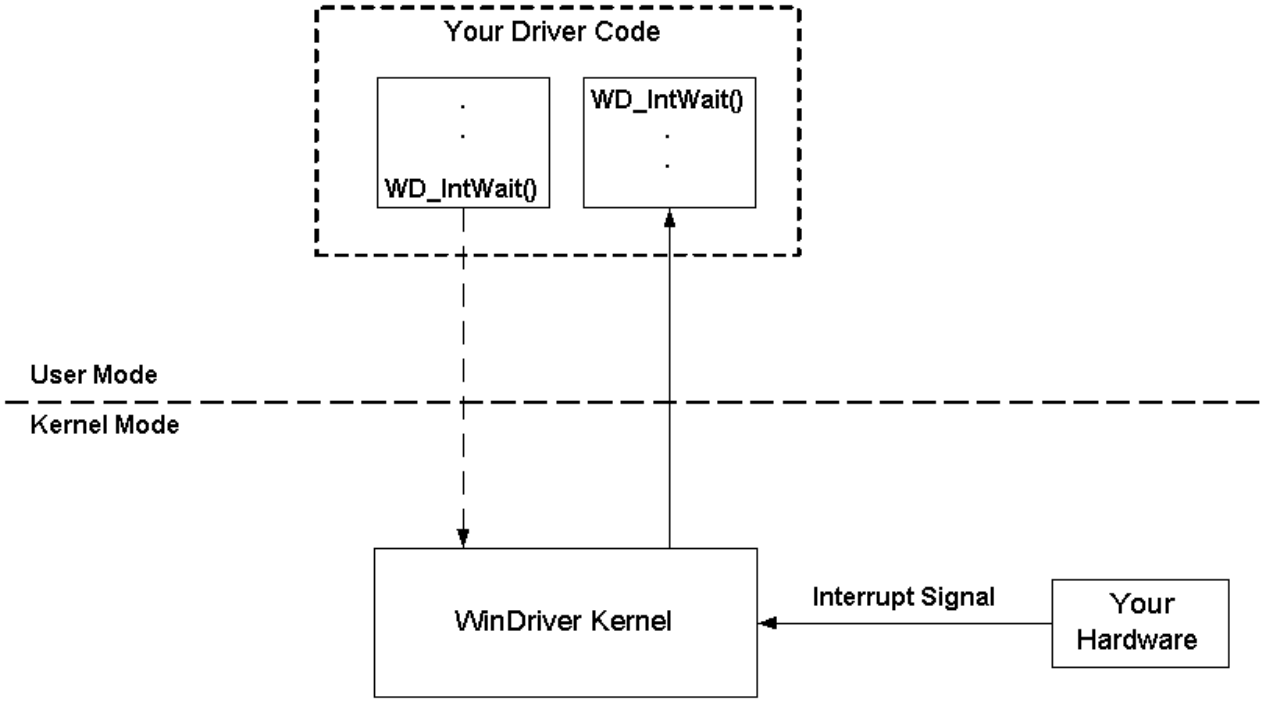
Interrupts will be handled in the Kernel PlugIn driver, if enabled, using a Kernel PlugIn driver, as explained below [11.6.5.2].

If Kernel PlugIn interrupts were enabled, when WinDriver receives a hardware interrupt, it calls the Kernel PlugIn driver's high-IRQL handler — `KP_IntAtIrql` [B.8.8] (legacy interrupts) or `KP_IntAtIrqlMSI` [B.8.10] (MSI/MSI-X). If the high-IRQL handler returns `TRUE`, the relevant deferred Kernel PlugIn interrupt handler — `KP_IntAtDpc` [B.8.9] (legacy interrupts) or `KP_IntAtDpcMSI` [B.8.11] (MSI/MSI-X) — will be called after the high-IRQL handler completes its processing and returns. The return value of the DPC function determines how many times (if at all) the user-mode interrupt handler routine will be executed. In the **KP_PCI** sample, for example, the Kernel PlugIn interrupt handler code counts five interrupts, and notifies the user mode on every fifth interrupt; thus `WD_IntWait`() (see the **WinDriver PCI Low-Level API Reference**) will return on only one out of every five incoming interrupts in the user mode. The high-IRQL handler — `KP_IntAtIrql` [B.8.8] or `KP_IntAtIrqlMSI` [B.8.10] — returns `TRUE` every five interrupts to activate the DPC handler — `KP_IntAtDpc` or `KP_IntAtDpcMSI` — and the DPC function returns the number of accumulated DPC calls from the high-IRQL handler. As a result, the user-mode interrupt handler will be executed once for every 5 interrupts.

11.6.5.1. Interrupt Handling in the User Mode (Without the Kernel PlugIn)

If the Kernel PlugIn interrupt handle is not enabled, then each incoming interrupt will cause `WD_IntWait`() to return, and your user-mode interrupt handler routine will be invoked once WinDriver completes the kernel processing of the interrupts (mainly executing the interrupt transfer commands passed in the call to `WDC_IntEnable`() [B.3.48] or the low-level `InterruptEnable`() or `WD_IntEnable`() functions — see the **WinDriver PCI Low-Level API Reference**) — see Figure 11.2.

Figure 11.2. Interrupt Handling Without Kernel PlugIn

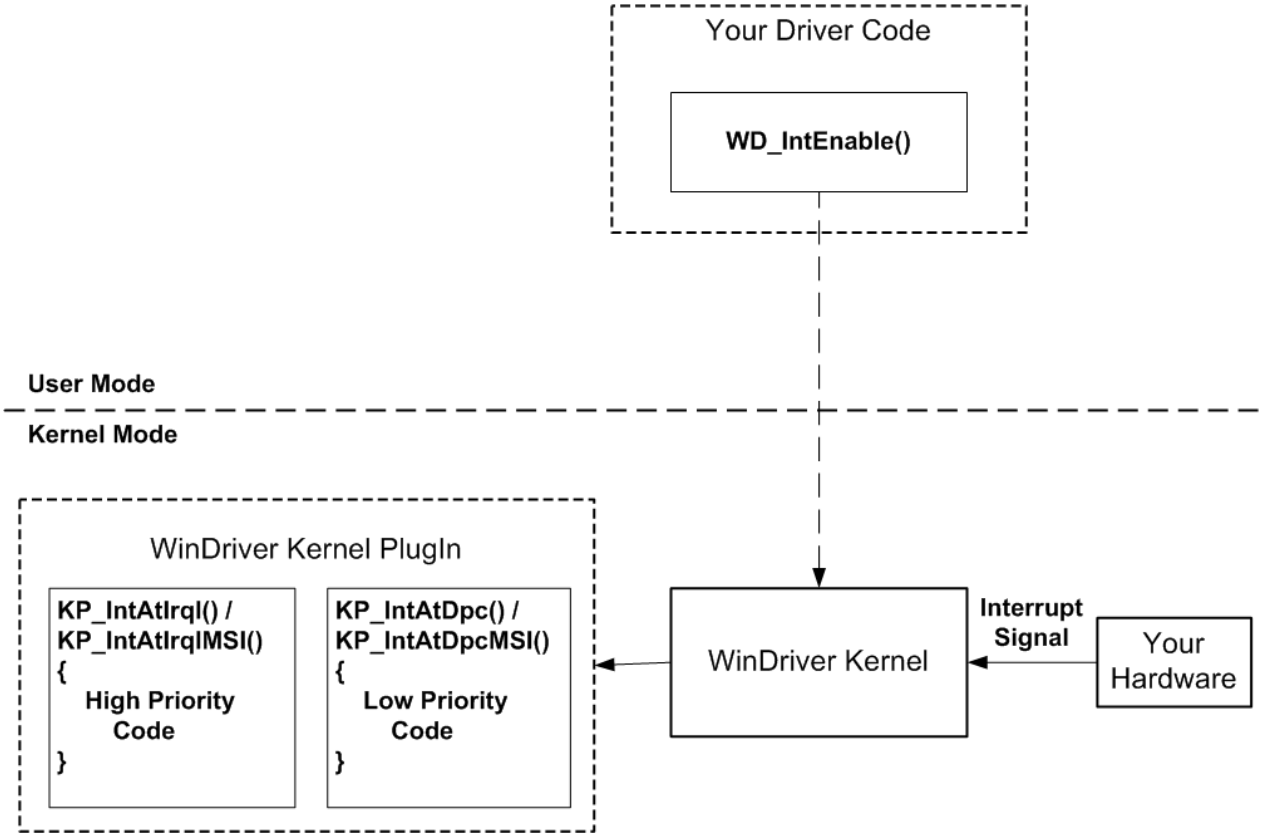


11.6.5.2. Interrupt Handling in the Kernel (Using the Kernel PlugIn)

To have the interrupts handled by the Kernel PlugIn, the user-mode application should open a handle to a Kernel PlugIn driver (as explained in Section 12.5), and then call `WDC_IntEnable`() [B.3.48] with the `fUseKP` parameter set to `TRUE`.

If your are not using the `WDC_xxx` API [B.2], your application should pass a handle to the Kernel PlugIn driver to the `WD_IntEnable`() function or the wrapper `InterruptEnable`() function (which calls `WD_IntEnable`() and `WD_IntWait`()). This enables the Kernel PlugIn interrupt handler. (The Kernel PlugIn handle is passed within the `hKernelPlugIn` field of the `WD_INTERRUPT` structure that is passed to the functions.) For details regarding the low-level `WD_xxx`() API, refer to the **WinDriver PCI Low-Level API Reference**.

Figure 11.3. Interrupt Handling With the Kernel PlugIn



When calling `WDC_IntEnable()` / `InterruptEnable()` / `WD_IntEnable()` to enable interrupts in the Kernel PlugIn, your Kernel PlugIn's `KP_IntEnable` callback function [B.8.6] is activated. In this function you can set the interrupt context that will be passed to the Kernel PlugIn interrupt handlers, as well as write to the device to actually enable the interrupts in the hardware and implement any other code required in order to correctly enable your device's interrupts.

If the Kernel PlugIn interrupt handler is enabled, then the relevant high-IRQL handler, based on the type of interrupt that was enabled — `KP_IntAtIrql` [B.8.8] (legacy interrupts) or `KP_IntAtIrqlMSI` [B.8.10] (MSI/MSI-X) — will be called for each incoming interrupt. The code in the high-IRQL handler is executed at high interrupt request level. While this code is running, the system is halted, i.e., there will be no context switches and no lower-priority interrupts will be handled.

Code running at high IRQL is limited in the following ways:

- It may only access non-pageable memory.
- It may only call the following functions (or wrapper functions that call these functions):
  - `WDC_xxx`() read/write address or configuration space functions.
  - `WDC_MultiTransfer`() [B.3.30], or the low-level `WD_Transfer`(), `WD_MultiTransfer`(), or `WD_DebugAdd`() functions (see the **WinDriver PCI Low-Level API Reference**).
  - Specific kernel OS functions (such as WDK functions) that can be called from high interrupt request level. Note that the use of such functions may break the code's portability to other operating systems.
- It may **not** call `malloc`(), `free`(), or any `WDC_xxx` or `WD_xxx` API other than those listed above.

Because of the aforementioned limitations, the code in the high-IRQL handler (`KP_IntAtIrql` [B.8.8] or `KP_IntAtIrqlMSI` [B.8.10]) should be kept to a minimum, such as acknowledgment (clearing) of level-sensitive interrupts. Other code that you want to run in the interrupt handler should be implemented in the DPC function (`KP_IntAtDpc` [B.8.9] or `KP_IntAtDpcMSI` [B.8.11]), which runs at a deferred interrupt level and does not face the same limitations as the high-IRQL handlers. The DPC function is called after its matching high-IRQL function returns, provided the high-IRQL handler returns `TRUE`.

You can also leave some additional interrupt handling to the user mode. The return value of your DPC function — `KP_IntAtDpc` [B.8.9] or `KP_IntAtDpcMSI` [B.8.11] — determines the amount of times (if any) that your user-mode interrupt handler routine will be called after the kernel-mode interrupt processing is completed.

11.6.6. Message Passing

The WinDriver architecture enables a kernel-mode function to be activated from the user mode by passing a message from the user mode to the Kernel PlugIn driver using `WDC_CallKerPlug`() [B.3.23] or the low-level `WD_KernelPlugInCall`() function (see the **WinDriver PCI Low-Level API Reference**).
The messages are defined by the developer in a header file that is common to both the user-mode and kernel-mode plugin parts of the driver. In the **pci_diag KP_PCI** sample and the generated DriverWizard code, the messages are defined in the shared library header file — **pci_lib.h** in the sample or **xxx_lib.h** in the generated code.

Upon receiving the message from the user mode, WinDriver will execute the `KP_Call` [B.8.4] Kernel PlugIn callback function, which identifies the message that has been received and executes the relevant code for this message (as implemented in the Kernel PlugIn).

The sample/generated Kernel PlugIn code implement a message for getting the driver's version in order to demonstrate Kernel PlugIn data passing. The code that sets the version number in `KP_Call` is executed in the Kernel PlugIn whenever the Kernel PlugIn receives a relevant message from the user-mode application. You can see the definition of the message in the shared **pci_lib.h** / **xxx_lib.h** shared header file. The user-mode application (**pci_diag.exe** / **xxx_diag.exe**) sends the message to the Kernel PlugIn driver via the `WDC_CallKerPlug`() function [B.3.23].

Chapter 12
Creating a Kernel PlugIn Driver

The easiest way to write a Kernel PlugIn driver is to use **DriverWizard** to generate the Kernel PlugIn code for your hardware (see Sections 11.6.3 and 11.6.4.2). Alternatively, you can use one of the WinDriver **Kernel PlugIn samples** as the basis for your Kernel PlugIn development. You can also develop your code "from scratch", if you wish.

As indicated in Section 11.6.3, the Kernel PlugIn documentation in this manual focuses on the generated DriverWizard code, and the generic PCI Kernel PlugIn sample — **KP_PCI**, located in the **WinDriver/samples/pci_diag/kp_pci** directory.
If you are using the a PCI Express card with the Xilinx Bus Master DMA (BMD) design, you can also use the **KP_BMD** Kernel PlugIn sample as the basis for your development; the **WinDriver/xilinx/bmd_design** directory contains all the relevant sample files — see the Xilinx BMD Kernel PlugIn directory structure note at the end of Section 11.6.4.1.

The following is a step-by-step guide to creating your Kernel PlugIn driver.

12.1. Determine Whether a Kernel PlugIn is Needed

The Kernel PlugIn should be used only after your driver code has been written and debugged in the user mode. This way, all of the logical problems of creating a device driver are solved in the user mode, where development and debugging are much easier.

Determine whether a Kernel PlugIn should be written by consulting Chapter 10, which explains how to improve the performance of your driver. In addition, the Kernel PlugIn affords greater flexibility, which is not always available when writing the driver in the user mode (specifically with regard to the interrupt handling).

12.2. What programming languages can be used with a Kernel PlugIn?

The Kernel PlugIn is a kernel module, and therefore must be written in the C language. The user application that calls the Kernel PlugIn can be of any langauge supported by WinDriver: C, C#.NET, Visual Basic.NET, Python.
When generating code in the DriverWizard in languages other than C with Kernel PlugIn, the Kernel PlugIn code will still be generated in C.

12.3. Prepare the User-Mode Source Code

1. Isolate the functions you need to move into the Kernel PlugIn.

2. Remove any platform-specific code from the functions. Use only functions that can also be used from the kernel.

3. Recompile your driver in the user mode.

4. Debug your driver in user mode again to see that your code still works after changes have been made.

- Keep in mind that the kernel stack is relatively limited in size. Therefore, code that will be moved into the Kernel PlugIn should not contain static memory allocations. Use the `malloc`() function to allocate memory dynamically instead. This is especially important for large data structures.

- If the user-mode code that you are porting to the kernel accesses memory addresses directly using the user-mode mapping of the physical address returned from the low-level `WD_CardRegister`() function — note that in the kernel you will need to use the kernel mapping of the physical address instead (the kernel mapping is also returned by `WD_CardRegister`()). For details, refer to the description of `WD_CardRegister`() in the **WinDriver PCI Low-Level API Reference**.
  When using the API of the **WDC** library [B.2] to access memory, you do not need to worry about this, since this API ensures that the correct mapping of the memory is used depending on whether the relevant APIs are used from the user mode or from the kernel mode.

12.4. Create a New Kernel PlugIn Project

As indicated above [12], you can use **DriverWizard** to generate a new Kernel PlugIn project (and a corresponding user-mode project) for your device (recommended), or use one of the WinDriver Kernel PlugIn samples as the basis for your development.

To successfully build a Kernel PlugIn project using MS Visual Studio, the path to the project directory must not contain any spaces.

If you select to start your development with the **KP_PCI** sample, follow these steps:

1. Make a copy of the **WinDriver/samples/pci_diag/kp_pci** directory. For example, to create a new Kernel PlugIn project called **KP_MyDrv**, copy **WinDriver/samples/pci_diag/kp_pci** to **WinDriver/samples/mydrv**.

2. Change all instances of "KP_PCI" and "kp_pci", in all the Kernel PlugIn files in your new directory, to "KP_MyDrv" and "kp_mydrv" (respectively).
   The names of the `KP_PCI_xxx`() functions in the **kp_pci.c** files do not have to be changed, but the code will be clearer if you use your selected driver name in the function names.

3. Change all occurrences of "KP_PCI" in file names to "kp_mydrv".

4. To use the shared **pci_lib** library API from your Kernel PlugIn driver and user-mode application, copy the **pci_lib.h** and **pci_lib.c** files from the **WinDriver/samples/pci_diag** directory to your new **mydrv** directory. You can change the names of the library functions to use your driver's name (**MyDrv**) instead of "PCI", but note that in this case you will also need to modify the names in all calls to these functions from your Kernel PlugIn project and user-mode application. If you do not copy the shared library to your new project, you will need to modify the sample Kernel PlugIn code and replace all references to the `PCI_xxx` library APIs with alternative code.

5. Modify the files and directory paths in the project and make files, and the #include paths in the source files, as needed (depending on the location in which you selected to save your new project directory).

6. To use the **pci_diag** user-mode application, copy **WinDriver/samples/pci_diag/pci_diag.c** and the relevant pci_diag project, solution, or make files to your **mydrv** directory, rename the files (if you wish), and replace all "pci_diag" references in the files with your preferred user-mode application name. To use the solution files, also replace the references to "KP_PCI" in the files with your new Kernel PlugIn driver, e.g., "KP_MyDrv". Then modify the sample code to implement your desired driver functionality.

For a general description of the sample and generated Kernel PlugIn code and its structure, see Sections 11.6.3 and 11.6.4 (respectively).

12.5. Open a Handle to the Kernel PlugIn

To open a handle to a Kernel PlugIn driver, `WD_KernelPlugIn`() (see the **WinDriver PCI Low-Level API Reference**) needs to be called from the user mode. This low-level function is called from `WDC_KernelPlugInOpen`() [B.3.22] — when it is called with the name of a Kernel PlugIn driver.

When using the high-level WDC API [B.2] you should use the following method to open a Kernel PlugIn handle:

- First open a regular device handle — by calling the relevant `WDC_xxxDeviceOpen`() function without the name of a Kernel PlugIn driver. Then call `WDC_KernelPlugInOpen`(), passing to it the handle to the opened device. `WDC_KernelPlugInOpen`() opens a handle to the Kernel PlugIn driver, and stores it within the `kerPlug` field of the provided device structure [B.4.2].

- Open a handle to the device, using the relevant `WDC_xxxDeviceOpen`() function, and pass the name of a Kernel PlugIn driver within the function's `pcKPDriverName` parameter. The device handle returned by the function will also contain (within the `kerPlug` field) a Kernel PlugIn handle opened by the function.

This method *cannot* be used to open a handle to a 64-bit Kernel PlugIn driver from a 32-bit application, or to open a Kernel PlugIn handle from a .NET application.

To ensure that your code works correctly in all the supported configurations, use the first method described above.

The generated DriverWizard and the sample **pci_diag** shared library (**xxx_lib.c** / **pci_lib.c**) demonstrate how to open a handle to the Kernel PlugIn — see the generated/sample `XXX_DeviceOpen`()/`PCI_DeviceOpen`() library function (which is called from the generated/sample **xxx_diag**/**pci_diag** user-mode application).

The handle to the Kernel PlugIn driver is closed when the `WD_KernelPlugInClose`() function (see the **WinDriver PCI Low-Level API Reference**) is called from the user mode. When using the low-level WinDriver API, this function is called directly from the user-mode application. When using the high-level WDC API [B.2], the function is called automatically when calling `WDC_xxxDeviceClose`() (PCI [B.3.19] / ISA [B.3.20]) with a device handle that contains an open Kernel PlugIn handle. The function is also called by WinDriver as part of the application cleanup, for any identified open Kernel PlugIn handles.

12.6. Set Interrupt Handling in the Kernel PlugIn

1. When calling `WDC_IntEnable`() [B.3.48] (after having opened a handle to the Kernel PlugIn driver, as explained in Section 12.5), set the `fUseKP` function parameter to `TRUE` to indicate that you wish to enable interrupts in the Kernel PlugIn driver with which the device was opened.
   The generated DriverWizard and the sample **pci_diag** shared library (**xxx_lib.c** / **pci_lib.c**) demonstrate how this should be done — see the generated/sample `XXX_IntEnable`()/`PCI_IntEnable`() library function (which is called from the generated/sample **xxx_diag**/**pci_diag** user-mode application).

   If you are not using the `WDC_xxx` API [B.2], in order to enable interrupts in the Kernel PlugIn call `WD_IntEnable`() or `InterruptEnable`() (which calls `WD_IntEnable`()), and pass the handle to the Kernel PlugIn driver that you received from `WD_KernelPlugInOpen`() (within the `hKernelPlugIn` field of the `WD_KERNEL_PLUGIN` structure that was passed to the function). For details regarding these APIs, refer to the **WinDriver PCI Low-Level API Reference**.

2. When calling `WDC_IntEnable`() / `InterruptEnable`() / `WD_IntEnable`(), to enable interrupts in the Kernel PlugIn, WinDriver will activate your Kernel PlugIn's `KP_IntEnable` callback function [B.8.6]. You can implement this function to set the interrupt context that will be passed to the high-IRQL and DPC Kernel PlugIn interrupt handler routines, as well as write to the device to actually enable the interrupts in the hardware, for example, or implement any other code required in order to correctly enable your device's interrupts.

3. Move the implementation of the user-mode interrupt handler, or the relevant portions of this implementation, to the Kernel PlugIn's interrupt handler functions. High-priority code, such as the code for acknowledging (clearing) level-sensitive interrupts, should be moved to the relevant high-IRQL handler — `KP_IntAtIrql` [B.8.8] (legacy interrupts)

or `KP_IntAtIrqlMSI` [B.8.10] (MSI/MSI-X) — which runs at high interrupt request level. Deferred processing of the interrupt can be moved to the relevant DPC handler — `KP_IntAtDpc` [B.8.9] or `KP_IntAtDpcMSI` [B.8.11] — which will be executed once the high-IRQL handler completes it processing and returns `TRUE`. You can also modify the code to make it more efficient, due to the advantages of handling the interrupts directly in the kernel, which provides you with greater flexibility (e.g., you can read from a specific register and write back the value that was read, or toggle specific register bits). For a detailed explanation on how to handle interrupts in the kernel using a Kernel PlugIn, refer to Section 11.6.5 of the manual.

12.7. Set I/O Handling in the Kernel PlugIn

1. Move your I/O handling code (if needed) from the user mode to the Kernel PlugIn message handler — `KP_Call` [B.8.4].

2. To activate the kernel code that performs the I/O handling from the user mode, call `WDC_CallKerPlug`() [B.3.23] or the low-level `WD_KernelPlugInCall`() function (see the **WinDriver PCI Low-Level API Reference**) with a relevant message for each of the different functionality that you wish to perform in the Kernel PlugIn.
   Implement a different message for each functionality.

3. Define these messages in a header file that is shared by the user-mode application (which will send the messages) and the Kernel PlugIn driver (that implements the messages).
   In the sample/generated DriverWizard Kernel PlugIn projects, the message IDs and other information that should be shared by the user-mode application and Kernel PlugIn driver are defined in the **pci_lib.h**/**xxx_lib.h** shared library header file.

12.8. Compile Your Kernel PlugIn Driver

The Kernel PlugIn is not backward compatible. Therefore, when switching to a different version of WinDriver, you need to rebuild your Kernel PlugIn driver using the new version.

12.8.1. Windows Kernel PlugIn Driver Compilation

The sample **WinDriver\samples\pci_diag\kp_pci** Kernel PlugIn directory and the generated DriverWizard Kernel PlugIn **<project_dir>\kermode** directory (where **<project_dir>** is the directory in which you selected to save the generated driver project) contain the following **Kernel PlugIn** project files (where **xxx** is the driver name — **pci** for the sample / the name you selected when generating the code with the wizard):

- **x86** — 32-bit project files:
  - **msdev_<version>\kp_xxx.vcproj** — 32-bit MS Visual Studio project file (where **<version>** signifies the IDE version — e.g., "2012")
  - **win_gcc/makefile** — 32-bit Windows GCC (MinGW/Cygwin) makefile

- **amd64** — 64-bit project files:
  - **msdev_<version>\kp_xxx.vcproj** — 64-bit MS Visual Studio project file (where **<version>** signifies the IDE version — e.g., "2012")
  - **win_gcc/makefile** — 64-bit Windows GCC (MinGW/Cygwin) makefile

The sample **WinDriver\samples\pci_diag** directory and the generated **<project_dir>** directory contain the following project files for the **user-mode** application that drives the respective Kernel PlugIn driver (where **xxx** is the driver name — **pci** for the sample / the name you selected when generating the code with the wizard):

- **x86** — 32-bit project files:
  - **msdev_<version>\xxx_diag.vcproj** — 32-bit MS Visual Studio project file (where **<version>** signifies the IDE version — e.g., "2012")
  - **win_gcc/makefile** — 32-bit Windows GCC (MinGW/Cygwin) makefile
- **amd64** — 64-bit project files:
  - **msdev_<version>\xxx_diag.vcproj** — 64-bit MS Visual Studio project file (where **<version>** signifies the IDE version — e.g., "2012")
  - **win_gcc/makefile** — 64-bit Windows GCC (MinGW/Cygwin) makefile

The **msdev_<version>** MS Visual Studio directories listed above also contain **xxx_diag.sln** solution files that include both the **Kernel PlugIn** and **user-mode** projects.

If you used DriverWizard to generate your code and you selected to generate a dynamic-link library (DLL) (Step 6.c), the generated **<project_dir>** directory will also have a **libproj** DLL project directory. This directory has **x86** (32-bit) and/or **amd64** (64-bit) directories that contain **msdev_<version>** directories for your selected IDEs, and each IDE directory has an **xxx_libapi.vcproj** project file for building the DLL. The DLL is used from the wizard-generated user-mode diagnostics project (**xxx_diag.vcproj**).

To build your Kernel PlugIn driver and respective user-mode application on Windows, follow these steps:

1. Verify that the Windows Driver Kit (WDK) is installed.
2. Set the **BASEDIR** environment variable to point to the location of the directory in which WDK is installed.
3. Build the **Kernel PlugIn SYS driver** (**kp_pci.sys** — sample / **kp_xxx.sys** — wizard-generated code):
   - Using MS Visual Studio — Start Microsoft Visual Studio, and do the following:

a. From your driver project directory, open the Visual Studio Kernel PlugIn solution file — **<project_dir>\msdev_<version>\xxx_diag.sln**, where **<project_dir>** is your driver project directory (**pci_diag** for the sample code / the directory in which you selected to save the generated DriverWizard code), **msdev_<version>** is your target Visual Studio directory (e.g., **msdev_2012**), and **xxx** is the driver name (**pci** for the sample / the name you selected when generating the code with the wizard).

- When using DriverWizard to generate code for MS Visual Studio, you can use the *IDE to Invoke* option to have the wizard automatically open the generated solution file in your selected IDE, after generating the code files.
- To successfully build a Kernel PlugIn project using MS Visual Studio, the path to the project directory must not contain any spaces.

b. Set the Kernel PlugIn project (**kp_pci.vcproj** / **kp_xxx.vcproj**) as the active project.

c. Select the active configuration for your target platform: From the **Build** menu, choose **Configuration Manager...**, and select the desired configuration.

To build the driver for multiple operating systems, select the lowest OS version that the driver must support. For example, to support Windows 7 and higher (32-bit), select either **Win32 win7 free** (release mode) or **Win32 win7 checked** (debug mode).

d. Build your driver: Build the project from the **Build** menu or using the relevant shortcut key (e.g., **F7** in Visual Studio 2008).

- Using Windows GCC — Do the following from your selected Windows GCC development environment (MinGW/Cygwin):

a. Change directory to your target Windows GCC Kernel PlugIn project directory — **<project_dir>/<kernel_dir>/<CPU>/win_gcc**, where **<project_dir>** is your driver project directory (**pci_diag** for the sample code / the directory in which you selected to save the generated DriverWizard code), **<kernel_dir>** is the project's Kernel PlugIn directory (**kp_pci** for the sample code / **kermode** for the generated code), and **<CPU>** is the target CPU architecture (**x86** for x86 platforms, and **amd64** for x64 platforms).

For example:

- When building a 32-bit version of the sample **KP_PCI** driver —
  `$ cd WinDriver/samples/pci_diag/kp_pci/x86/win_gcc`
- When building a 64-bit wizard-generated Kernel PlugIn driver —
  `$ cd <project_dir>/kermode/amd64/win_gcc`
  — where **<project_dir>** signifies the path to your generated DriverWizard project directory (for example, **~/WinDriver/wizard/my_projects/my_kp**).

b. Edit the **ddk_make.bat** command in the Kernel PlugIn makefile, to set the desired build configuration — namely, the target OS and build mode (release — `free`, or debug — `checked`). By default, the WinDriver sample and wizard-generated makefiles set the target OS parameter to Windows 7 (`win7` for 32-bit / `x64` for 64-bit), and the build mode to release (`free`).

- The **ddk_make.bat** utility is provided under the **WinDriver\util** directory, and should be automatically identified by Windows when running the build command. Run **`ddk_make.bat`** with no parameters to view the available options for this utility.
- The selected build OS must match the CPU architecture of your WinDriver installation. For example, you cannot select the 64-bit `win7_x64` OS flag when using a 32-bit WinDriver installation.
- To build the driver for multiple operating systems, select the lowest OS version that the driver must support. For example, to support Windows 7 and higher, set the OS parameter to `win7` (for 32-bit) or `x64` (for 64-bit).

c. Build the Kernel PlugIn driver using the **`make`** command.

4. Build the **user-mode application** that drives the Kernel PlugIn driver (**pci_diag.exe** — sample / **xxx_diag.exe** — wizard-generated code):

   - Using MS Visual Studio —

     1. Set the user-mode project (**pci_diag.vcproj** — sample / **xxx_diag.vcproj** — wizard-generated code) as the active project.

     2. Build the application: Build the project from the **Build** menu or using the relevant shortcut key (e.g., **F7** in Visual Studio 2008).

- Using Windows GCC — Do the following from your selected Windows GCC development environment (MinGW/Cygwin):

  a. Change directory to your target Windows GCC application directory — **<project_dir>/<CPU>/win_gcc**, where **<project_dir>** is your driver project directory (**pci_diag** for the sample code / the directory in which you selected to save the generated DriverWizard code), and **<CPU>** is the target CPU architecture (**x86** for x86 platforms, and **amd64** for x64 platforms).

  For example:

  - When building a 32-bit version of the sample **pci_diag** application, which drives the sample **KP_PCI** driver —
    `$ cd WinDriver/samples/pci_diag/x86/win_gcc`

  - When building a 64-bit wizard-generated user-mode application that drivers a wizard-generated Kernel PlugIn driver —
    `$ cd <project_dir>/amd64/win_gcc`
    — where **<project_dir>** signifies the path to your generated DriverWizard project directory (for example, **~/WinDriver/wizard/my_projects/my_kp**).

  b. Build the application using the **`make`** command.

12.8.2. Linux Kernel PlugIn Driver Compilation

To build your Kernel PlugIn driver and respective user-mode application on Linux, follow these steps:

1. Open a shell terminal.

2. Change directory to your Kernel PlugIn directory.

   For example:

   - When building the sample **KP_PCI** driver —
     `$ cd WinDriver/samples/pci_diag/kp_pci`

   - When building a wizard-generated Kernel PlugIn driver —
     `$ cd <project_dir>/kermode/linux/`
     — where **<project_dir>** signifies the path to your generated DriverWizard project directory (for example, **~/WinDriver/wizard/my_projects/my_kp**).

3. Generate the **makefile** using the **configure** script:
   `$ ./configure`

If you have renamed the WinDriver kernel module [15.2], be sure to uncomment the following line in your Kernel PlugIn configuration script (by removing the pound sign — "#"), before executing the script, in order to build the driver with the **-DWD_DRIVER_NAME_CHANGE** flag (see Section 15.2.2, Step 3):
```
# ADDITIONAL_FLAGS="-DWD_DRIVER_NAME_CHANGE"
```

- The configuration script creates a makefile based on the running kernel. You may select to use another installed kernel source, by executing the script with the **--with-kernel-source=<path>** option, where **<path>** is the full path to the kernel source directory — e.g., **/usr/src/linux**.

- If the Linux kernel version is 2.6.26 or higher, the configuration script generates makefiles that use **kbuild** to compile the kernel modules. You can force the use of **kbuild** on earlier versions of Linux, by executing the configuration script with the **--enable-kbuild** flag.

For a full list of the configuration script options, use the **--help** option:
```
./configure --help
```

4. Build the Kernel PlugIn module using the **make** command.
   This command creates a new **LINUX.<kernel version>.<CPU>** directory, which contains the created **kp_xxx_module.o/.ko** driver.

5. Change directory to the directory that holds the makefile for the sample user-mode diagnostics application.

   For the **KP_PCI** sample driver —
   ```
   $ cd ../LINUX/
   ```

   For the generated DriverWizard Kernel PlugIn driver —
   ```
   $ cd ../../linux/
   ```

6. Compile the sample diagnostics program using the **make** command.

12.9. Install Your Kernel PlugIn Driver

12.9.1. Windows Kernel PlugIn Driver Installation

Driver installation on Windows requires administrator privileges.

The following steps can also be performed with the **wdreg_frontend.exe** GUI application. For additional information, refer to [13.3].

1. Copy the driver file (**xxx.sys**) to the target platform's drivers directory: **%windir%\system32\drivers** (e.g., **C:\WINDOWS\system32\drivers**).

2. Register/load your driver, using the **wdreg.exe** or **wdreg_gui.exe** utility:

   In the following instructions, **KP_NAME** stands for your Kernel PlugIn driver's name, *without* the .sys extension.

   To install your driver, run this command:
   ```
   WinDriver\util> wdreg -name KP_NAME install
   ```

Kernel PlugIn drivers are dynamically loadable — i.e., they can be loaded and unloaded without reboot. For additional information, refer to Section 13.2.3.

12.9.2. Linux Kernel PlugIn Driver Installation

1. Change directory to your Kernel PlugIn driver directory.

   For example, when installing the sample **KP_PCI** driver, run
   ```
   $ cd WinDriver/samples/pci_diag/kp_pci
   ```

   When installing a driver created using the Kernel PlugIn files generated by DriverWizard, run the following command, where **<path>** signifies the path to your generated DriverWizard project directory (e.g., **~/WinDriver/wizard/my_projects/my_kp**):
   ```
   $ cd <path>/kermode/
   ```

2. Execute the following command to install your Kernel PlugIn driver:

   The following command must be executed with root privileges.

   ```
   # make install
   ```

Kernel PlugIn drivers are dynamically loadable — i.e., they can be loaded and unloaded without reboot. For additional information, refer to Section 13.5.1.

Chapter 13
Dynamically Loading Your Driver

13.1. Why Do You Need a Dynamically Loadable Driver?

When adding a new driver, you may be required to reboot the system in order for it to load your new driver into the system. WinDriver is a dynamically loadable driver, which enables your customers to start your application immediately after installing it, without the need for reboot. You can dynamically load your driver whether you have created a user-mode or a kernel-mode (Kernel PlugIn [11]) driver.

To successfully unload your driver, make sure that there are no open handles to the WinDriver service (**windrvr1281.sys** or your renamed driver [15.2]), and that there are no connected and enabled Plug-and-Play devices that are registered with this service.

13.2. Windows Dynamic Driver Loading

Windows 7 and higher uses Windows Driver Model (WDM) drivers [2.3.1]: Files with the extension ***.sys** (e.g., **windrvr1281.sys**).
WDM drivers are installed via the installation of an INF file (see below).

The WinDriver Windows kernel module — **windrvr1281.sys** — is a fully WDM driver, which can be installed using the **wdreg** utility, as explained in the following sections.

13.2.1. The wdreg Utility

WinDriver provides a utility for dynamically loading and unloading your driver, which replaces the slower manual process using Windows' Device Manager (which can still be used for the device INF). This utility is provided in two forms: **wdreg** and **wdreg_gui**. Both versions can be found in the **WinDriver\util** directory, can be run from the command line, and provide the same functionality. The difference is that **wdreg_gui** displays installation messages graphically, while **wdreg** displays them in console mode.

This section describes the use of **wdreg**/ **wdreg_gui** on Windows operating systems.

1. **wdreg** is dependent on the Driver Install Frameworks API (**DIFxAPI**) DLL — **difxapi.dll**, unless when run with the **`-compat`** option (described below). **difxapi.dll** is provided under the **WinDriver\util** directory.

2. The explanations and examples below refer to **wdreg**, but any references to **wdreg** can be replaced with **wdreg_gui**.

13.2.1.1. WDM Drivers

This section explains how to use the **wdreg** utility to install the WDM **windrvr1281.sys** driver, or to install INF files that register Plug-and-Play devices (such as PCI) to work with this driver, on Windows.

You can rename the **windrvr1281.sys** kernel module and modify your device INF file to register with your renamed driver, as explained in Section 15.2.1. To install your modified INF files using **wdreg**, simply replace any references to **windrvr1281** below with the name of your new driver.

This section is **not relevant** for **Kernel PlugIn** drivers, since these are not WDM drivers and are not installed via an INF file. For an explanation on how to use **wdreg** to install Kernel PlugIn drivers on Windows, refer to Section 13.2.1.2.

Usage: The **wdreg** utility can be used in two ways as demonstrated below:

1. **`wdreg -inf <filename> [-silent] [-log <logfile>] [install | preinstall | uninstall | enable | disable]`**

2. **`wdreg -rescan <enumerator> [-silent] [-log <logfile>]`**

- OPTIONS
  wdreg supports several basic OPTIONS from which you can choose one, some, or none:

  - **-inf** — The path of the INF file to be dynamically installed.

  - **-rescan <enumerator>** — Rescan enumerator (ROOT, ACPI, PCI, etc.) for hardware changes. Only one enumerator can be specified.

  - **-silent** — Suppress display of all messages (optional).

  - **-log <logfile>** — Log all messages to the specified file (optional).

  - **-compat** — Use the traditional **SetupDi** API instead of the newer Driver Install Frameworks API (**DIFxAPI**).

- ACTIONS
  wdreg supports several basic ACTIONS:

- **install** — Installs the INF file, copies the relevant files to their target locations, and dynamically loads the driver specified in the INF file name by replacing the older version (if needed).
- **preinstall** Pre-installs the INF file for a non-present device.
- **uninstall** — Removes your driver from the registry so that it will not load on next boot (see note below).
- **enable** — Enables your driver.
- **disable** — Disables your driver, i.e., dynamically unloads it, but the driver will reload after system boot (see note below).

To successfully disable/uninstall your driver, make sure that there are no open handles to the WinDriver service (**windrvr1281.sys** or your renamed driver [15.2]), and that there are no connected and enabled Plug-and-Play devices that are registered with this service.

13.2.1.2. Non-WDM Drivers

This section explains how to use the **wdreg** utility to install non-WDM drivers, namely Kernel PlugIn drivers, on Windows.

Usage:

```
wdreg [-file <filename>] [-name <drivername>] [-startup <level>]
[-silent] [-log <logfile>] Action [Action ...]
```

- OPTIONS
  wdreg supports several basic OPTIONS from which you can choose one, some, or none:
  - **-startup**: Specifies when to start the driver. Requires one of the following arguments:
    - **boot**: Indicates a driver started by the operating system loader, and should only be used for drivers that are essential to loading the OS (for example, Atdisk).
    - **system**: Indicates a driver started during OS initialization.
    - **automatic**: Indicates a driver started by the Service Control Manager during system startup.
    - **demand**: Indicates a driver started by the Service Control Manager on demand (i.e., when your device is plugged in).
    - **disabled**: Indicates a driver that cannot be started.

The default setting for the **-startup** option is **automatic**.

- **-name** — Sets the symbolic name of the driver. This name is used by the user-mode application to get a handle to the driver. You must provide the driver's symbolic name (*without* the *.sys extension) as an argument with this option. The argument should be equivalent to the driver name as set in the `KP_Init` [B.8.1] function of your Kernel PlugIn project: **`strcpy(kpInit->cDriverName, XX_DRIVER_NAME)`** .

- **-file** — **wdreg** allows you to install your driver in the registry under a different name than the physical file name. This option sets the file name of the driver. You must provide the driver's file name (*without* the *.sys extension) as an argument.
  wdreg looks for the driver in the Windows installation directory (**%windir%\system32\drivers**). Therefore, you should verify that the driver file is located in the correct directory before attempting to install the driver.

  Usage:
  `wdreg -name <Your new driver name> -file <Your original driver name> install`

- **-silent** — Suppresses the display of messages of any kind.

- **-log <logfile>** — Logs all messages to the specified file.

- ACTIONS
  wdreg supports several basic ACTIONS:

  - **create** — Instructs Windows to load your driver next time it boots, by adding your driver to the registry.

  - **delete** — Removes your driver from the registry so that it will not load on next boot.

  - **start** — Dynamically loads your driver into memory for use. You must create your driver before starting it.

  - **stop** — Dynamically unloads your driver from memory.

- Shortcuts
  wdreg supports a few shortcut operations for your convenience:

  - **install** — Creates and starts your driver.
    This is the same as first using the wdreg **`stop`** action (if a version of the driver is currently loaded) or the wdreg **`create`** action (if no version of the driver is currently loaded), and then the wdreg **`start`** action.

  - **preinstall** — Creates and starts your driver for a non-connected device.

  - **uninstall** — Unloads your driver from memory and removes it from the registry so that it will not load on next boot.
    This is the same as first using the wdreg **`stop`** action and then the wdreg **`delete`** action.

13.2.2. Dynamically Loading/Unloading windrvr1281.sys INF Files

When using WinDriver, you develop a user-mode application that controls and accesses your hardware by using the generic **windrvr1281.sys** driver (WinDriver's kernel module). Therefore, you might want to dynamically load and unload the driver **windrvr1281.sys** — which you can do using **wdreg**.
In addition, in WDM-compatible operating systems, you also need to dynamically load INF files for your Plug-and-Play devices. **wdreg** enables you to do so automatically on Windows.
This section includes **wdreg** usage examples, which are based on the detailed description of **wdreg** contained in the previous section. Examples:

- To load **windrvr1281.inf** and start the **windrvr1281.sys** service —
  `wdreg -inf <path to windrvr1281.inf> install`

- To load an INF file named **device.inf**, located in the **c:\tmp** directory —
  `wdreg -inf c:\tmp\device.inf install`

  You can replace the `install` option in the example above with `preinstall` to pre-install the device INF file for a device that is not currently connected to the PC.

If the installation fails with an `ERROR_FILE_NOT_FOUND` error, inspect the Windows registry to see if the `RunOnce` key exists in `HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\Windows\CurrentVersion`. This registry key is required by Windows Plug-and-Play in order to properly install drivers using INF files. If the `RunOnce` key is missing, create it; then try installing the INF file again.

To unload the driver/INF file, use the same commands, but simply replace `install` in the examples above with `uninstall`.

13.2.3. Dynamically Loading/Unloading Your Kernel PlugIn Driver

If you used WinDriver to develop a Kernel PlugIn driver [11], you must load this driver only after loading the generic WinDriver driver — **windrvr1281.sys**.
When unloading the drivers, unload your Kernel PlugIn driver before unloading **windrvr1281.sys**.

Kernel PlugIn drivers are dynamically loadable — i.e., they can be loaded and unloaded without reboot. To load/unload your Kernel PlugIn driver (**<Your driver name>.sys**) use the **wdreg** command as described above for windrvr1281, with the addition of the 'name' flag, after which you must add the name of your Kernel PlugIn driver.

You should **not** add the *.sys extension to the driver name.

Examples:

- To load a Kernel PlugIn driver called **KPDriver.sys**, run this command:
  `wdreg -name KPDriver install`
- To load a Kernel PlugIn driver called MPEG_Encoder, with file name **MPEGENC.sys**, run this command:
  `wdreg -name MPEG_Encoder -file MPEGENC install`
- To uninstall a Kernel PlugIn driver called **KPDriver.sys**, run this command:
  `wdreg -name KPDriver uninstall`
- To uninstall a Kernel PlugIn driver called MPEG_Encoder, with file name MPEGENC.sys, run this command:
  `wdreg -name MPEG_Encoder -file MPEGENC uninstall`

13.3. The wdreg_frontend utility

Under Windows, WinDriver features a GUI frontend utility that is designed to ease installataion/ uninstallation of WinDriver and Kernel PlugIn drivers during development phases. Every operation that can be performed with **`wdreg`** can also be performend from **`wdreg_frontend`** and their output is identical. **`wdreg_frontend`** prints out the complete **`wdreg`** command that it performed, making it easier for the developer to copy the desired command and integrate it in their own installation scripts.

Driver installation on Windows requires administrator privileges.

Loading **`wdreg_frontend`**:

Figure 13.1. The wdreg_frontend icon

- Click the **`wdreg_frontend`** icon from the **DriverWizard** window.
- Run **`WinDriver/util/wdreg_frontend.exe`** directly.

To load/unload a Kernel Plugin:

Figure 13.2. The dialog box wdreg_frontend will open if driver file is not located in the Windows system directory

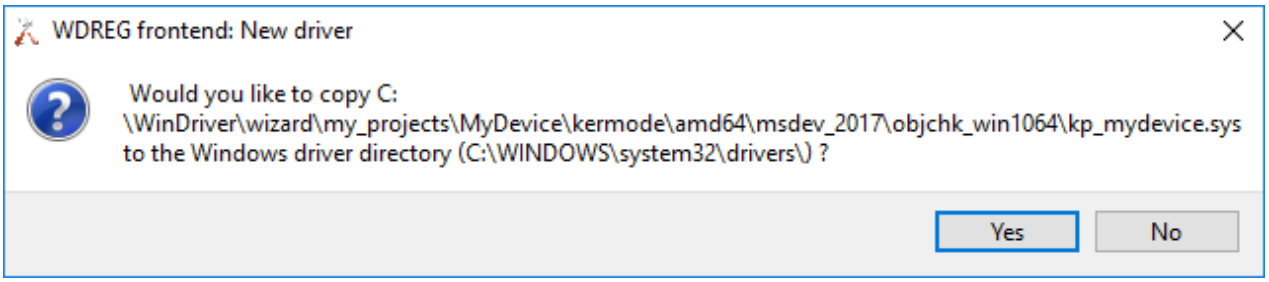
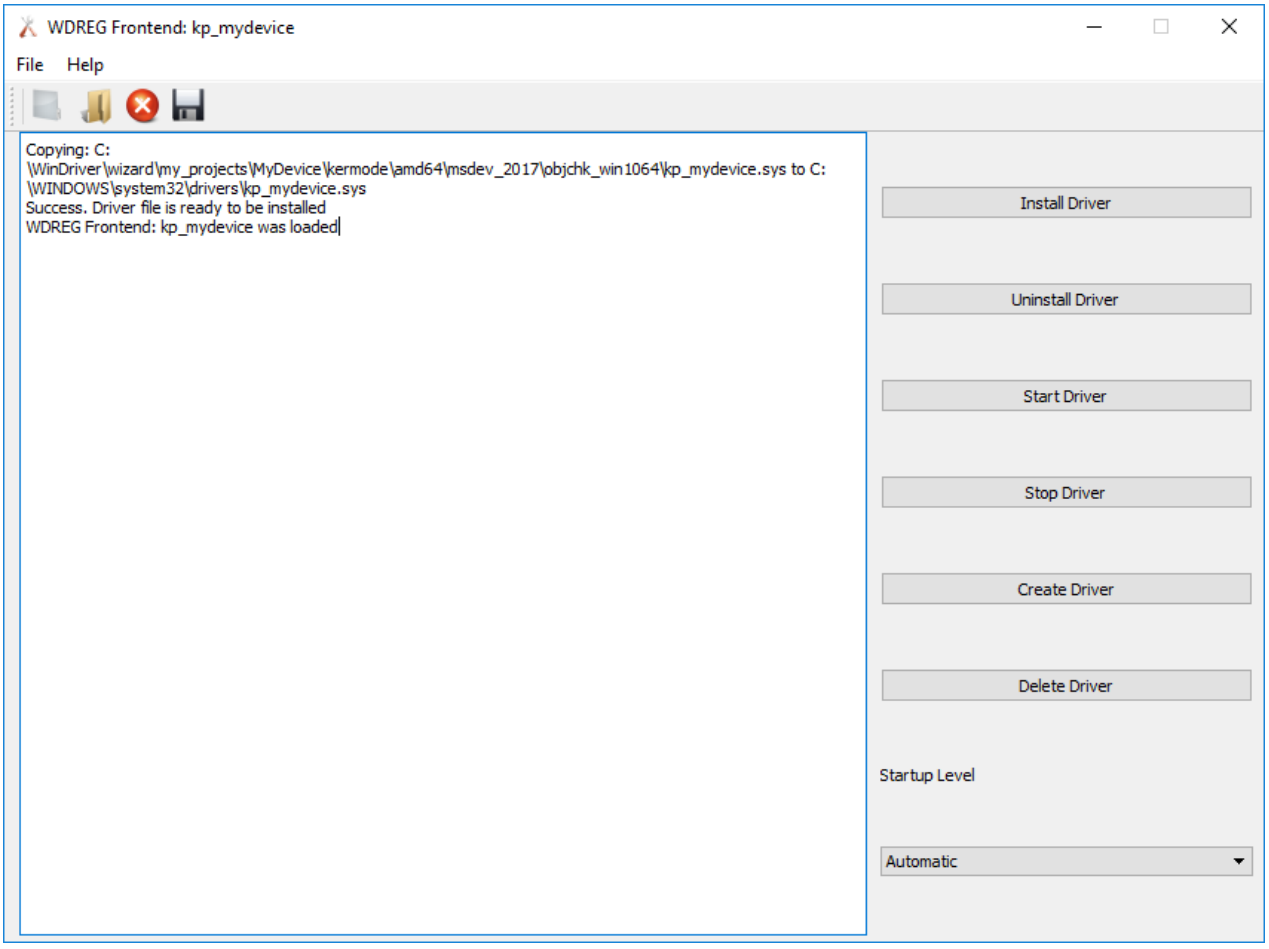
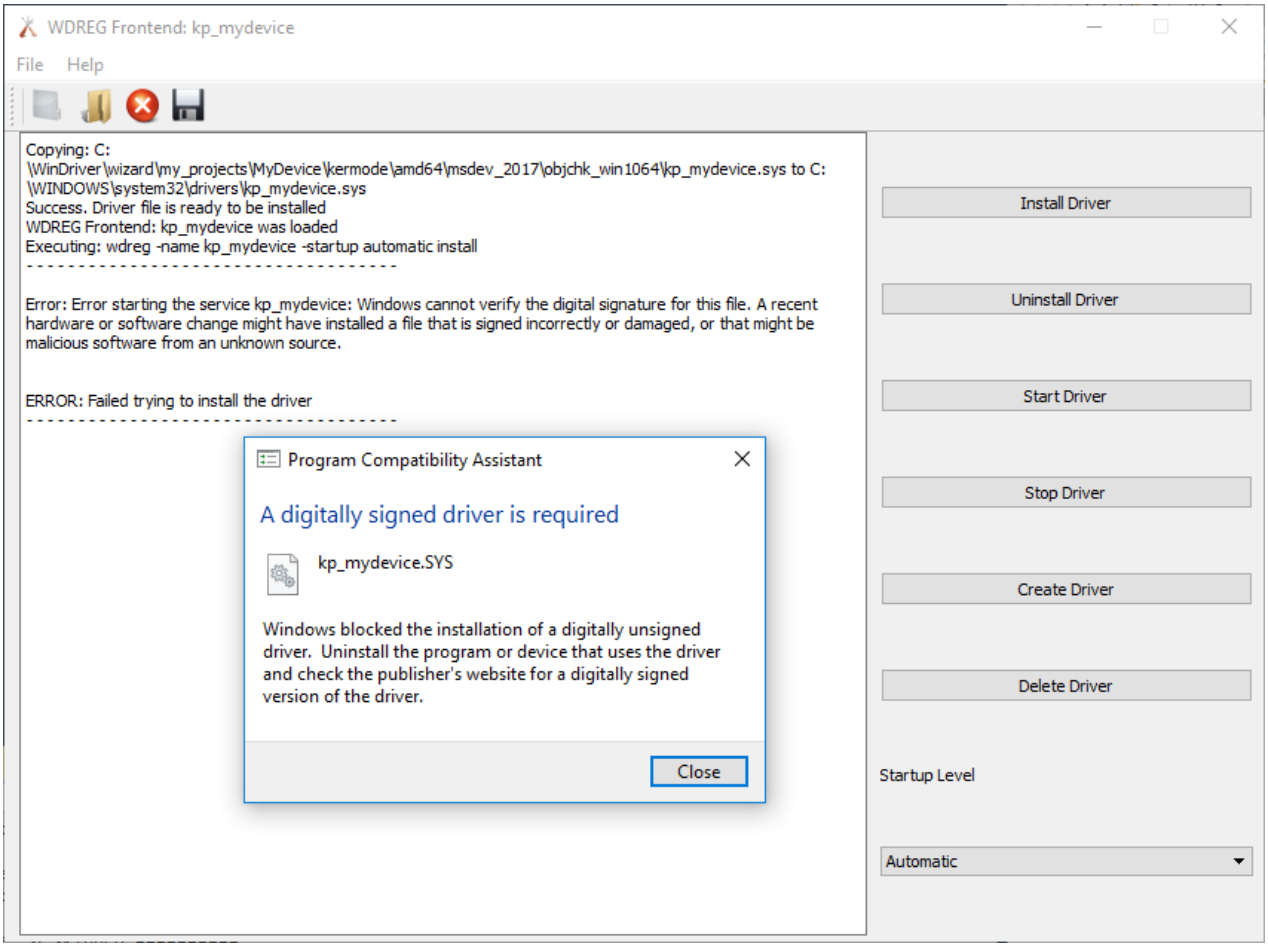


Figure 13.3. wdreg_frontend after successfully loading a sys file



- Click **File->Open** and open the desired sys file.
- If the sys file is not located in the Windows system directory, a dialog box will appear and ask if you wish **`wdreg_frontend`** to copy the sys file to the Windows system directory.
- If the file loaded correctly, all actions available for .sys files will become enabled: **Install Driver, Uninstall Driver, Start Driver, Stop Driver, Create Driver, Delete Driver** and choice of **Startup level**. Further information on these actions is available on the wdreg section of this document. [13.2.1.2]:

Figure 13.4. Error message given by Windows when trying to install an unsigned driver

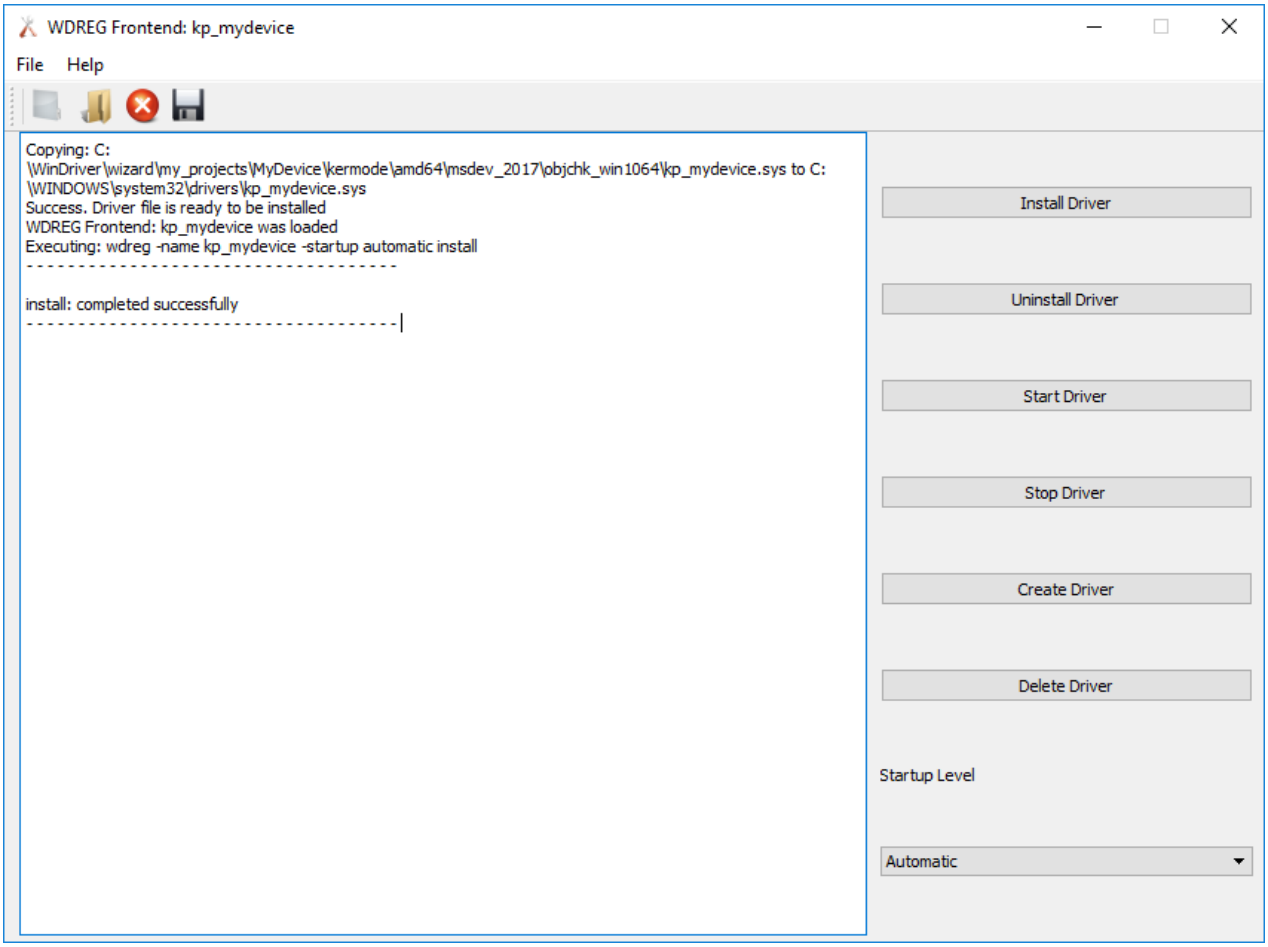


You may need to either digitally sign your sys file or disable digital signature enforcement for the driver to properly load and work under Windows.

To install/uninstall an INF file:

- Click **File->Open** and open the desired sys file.
- If the file loaded correctly, all actions available for .inf files will become enabled: **Install Driver, Uninstall Driver, Enable Driver, Disable Driver, Preinstall Driver** Further information on these actions is available on the wdreg section of this document. [13.2.1.1]:

Figure 13.5. wdreg_frontend upon successfully installing a sys driver



13.4. Windows 10 IoT Core Dynamic Driver Loading

If you can connect your PCI/USB device to your development computer you can create an INF file as described in [4.2].
If you cannot connect your PCI/USB device to your development computer then do the following:

1. Create a project for a **Virtual Device**, as described in [4.2].
2. Manually enter your VID, PID, Manufacturer and Device name in the INF file you've created in the previous step.
3. Transfer the project files to your Windows 10 IoT Core target computer.

To load your driver do the following:

1. Copy the INF file you have created to your Windows 10 IoT Core target compter, and put it in the directory that holds **wdreg_iot.cmd**.

2. Install WinDriver for your PCI/USB device using the **wdreg_iot.cmd** script:
   `wdreg_iot.cmd install xxx.inf`

13.5. Linux Dynamic Driver Loading

The following commands must be executed with root privileges.

- To dynamically load WinDriver, run the following command:
  `# <path to wdreg> windrvr1281`

- To dynamically unload WinDriver, run the following command:
  `# /sbin/modprobe -r windrvr1281`.

wdreg is provided in the **WinDriver/util** directory.

To automatically load WinDriver on each boot, add the following line to the target's Linux boot file (for example, **/etc/rc.local**):
`<path to wdreg> windrvr1281`

13.5.1. Dynamically Loading/Unloading Your Kernel PlugIn Driver

If you used WinDriver to develop a Kernel PlugIn driver [11], you must load this driver only after loading the generic WinDriver driver — **windrvr1281.o/.ko**.
When unloading the drivers, unload your Kernel PlugIn driver before unloading **windrvr1281.o/.ko**.

Kernel PlugIn drivers are dynamically loadable — i.e., they can be loaded and unloaded without reboot. Use the following commands to dynamically load or unload your Kernel PlugIn driver.

The following commands must be executed with root privileges.

xxx in the commands signifies your selected Kernel PlugIn driver project name.

- To dynamically load your Kernel PlugIn driver, run this command:
  # /sbin/insmod <path to kp_xxx_module.o/.ko>

When building the Kernel PlugIn driver on the development machine, the Kernel PlugIn driver module is created in your Kernel PlugIn project's **kermode/linux/LINUX.<kernel version>.<CPU>** directory (see Section 12.8.2, Step 4). When building the driver on a target distribution machine, the driver module is normally created in an **xxx_installation/redist/LINUX.<kernel version>.<CPU>.KP** directory (see Section 14.3.3, Step 2).

- To dynamically unload your Kernel PlugIn, run this command:
  # /sbin/rmmod kp_xxx_module

To automatically load your Kernel PlugIn driver on each boot, add the following line to the target's Linux boot file (for example, **/etc/rc.local**), after the WinDriver driver module (**windrvr1281**) load command (replace **<path to kp_xxx_module.o/.ko>** with the path to your Kernel PlugIn driver module):
`/sbin/insmod <path to kp_xxx_module.o/.ko>`

Chapter 14
Distributing Your Driver

Read this chapter in the final stages of driver development. It will guide you in preparing your driver for distribution.

14.1. Getting a Valid WinDriver License

Before distributing your driver you must purchase a WinDriver license, as outlined in Appendix F.
Then install the registered version of WinDriver on your development machine by following the installations in Section 3.2. If you have already installed an evaluation version of WinDriver, you can jump directly to the installation steps for registered users to activate your license.
To register code developed during the evaluation period of WinDriver, follow the instructions in Section 3.3.

14.2. Windows Driver Distribution

- All references to **wdreg** in this section can be replaced with **wdreg_gui**, which offers the same functionality as **wdreg** but displays GUI messages instead of console-mode messages.

- If you have renamed the WinDriver kernel module (**windrvr1281.sys**), as explained in Section 15.2, replace the relevant **windrvr1281** references with the name of your driver, and replace references to the **WinDriver\redist** directory with the path to the directory that contains your modified installation files. For example, when using the generated DriverWizard renamed driver files for your driver project, as explained in Section 15.2.1, you can replace references to the **WinDriver\redist** directory with references to the generated **xxx_installation\redist** directory (where **xxx** is the name of your generated driver project). Note also the option to simplify the installation using the generated DriverWizard **xxx_install.bat** script and the copies of the **WinDriver\util** installation files in the generated **xxx_installation\redist** directory, as explained in Section 15.2.1.

- If you have created new INF and/or catalog files for your driver, replace the references to the original WinDriver INF files and/or to the **windrvr1281.cat** catalog file with the names of your new files (see the file renaming information in Sections 15.2.1 and 15.3.2).

Distributing the driver you created is a multi-step process. First, create a distribution package that includes all the files required for the installation of the driver on the target computer. Second, install the driver on the target machine. This involves installing **windrvr1281.sys** and **windrvr1281.inf**, installing the specific INF file for your device (for Plug-and-Play hardware — PCI/PCI Express), and installing your Kernel PlugIn driver (if you have created one).

Finally, you need to install and execute the hardware-control application that you developed with WinDriver. These steps can be performed using **wdreg** utility.

14.2.1. Preparing the Distribution Package

Prepare a distribution package that includes the following files.

If you wish to distribute drivers for both 32-bit and 64-bit target platforms, you must prepare separate distribution packages for each platform. The required files for each package are provided in the WinDriver installation directory for the respective platform.

- Your hardware-control application/DLL.
- **windrvr1281.sys**.
  Get this file from the **WinDriver\redist** directory of the WinDriver package.
- **windrvr1281.inf**.
  Get this file from the **WinDriver\redist** directory of the WinDriver package.
- **windrvr1281.cat**
  Get this file from the **WinDriver\redist** directory of the WinDriver package.
- **wdapi1281.dll** (for distribution of 32-bit binaries to 32-bit target platforms or for distribution of 64-bit binaries to 64-bit platforms) or **wdapi1281_32.dll** (for distribution of 32-bit binaries to 64-bit platforms [A.2].
  Get this file from the **WinDriver\redist** directory of the WinDriver package.
- **difxapi.dll** (required by the **wdreg.exe** utility [13.2.1]).
  Get this file from the **WinDriver\util** directory of the WinDriver package.
- An INF file for your device (required for Plug-and-Play devices, such as PCI).
  You can generate this file with DriverWizard, as explained in Section 4.2.
- If you have created a Kernel PlugIn driver [11]: Your Kernel PlugIn driver — **<KP driver name>.sys**.

14.2.2. Installing Your Driver on the Target Computer

Driver installation on Windows requires administrator privileges.

Follow the instructions below in the order specified to properly install your driver on the target computer:

- **Preliminary Steps:**
  To successfully install your driver, make sure that there are no open handles to the WinDriver service (**windrvr1281.sys** or your renamed driver [15.2]), and that there are no connected and enabled Plug-and-Play devices that are registered with this service. If the service is being used, attempts to install the new driver using **wdreg** will fail. This is relevant, for example, when upgrading from an earlier version of the driver that uses the same driver name. You can disable or uninstall connected devices from the Device Manager (**Properties | Disable/Uninstall**) or using **wdreg**, or otherwise physically disconnect the device(s) from the PC.

  Since v11.9.0 of WinDriver, the default driver module name includes the WinDriver version, so if you do not rename the driver to a previously-used name there should not be conflicts with older drivers.

- **Install WinDriver's kernel module:**

  1. Copy **windrvr1281.sys**, **windrvr1281.inf**, and **windrvr1281.cat** to the same directory.

     windrvr1281.cat contains the driver's Authenticode digital signature. To maintain the signature's validity this file must be found in the same installation directory as the **windrvr1281.inf** file. If you select to distribute the catalog and INF files in different directories, or make any changes to these files or to any other files referred to by the catalog file (such as **windrvr1281.sys**), you will need to do either of the following:
     - Create a new catalog file and re-sign the driver using this file.
     - Comment-out or remove the following line in the **windrvr1281.inf** file:
       `CatalogFile=windrvr1281.cat`
       and do not include the catalog file in your driver distribution. However, note that this option invalidates the driver's digital signature.

     For more information regarding driver digital signing and certification and the signing of your WinDriver-based driver, refer to Section 15.3 of the manual.

  2. Use the utility **wdreg** to install WinDriver's kernel module on the target computer:
     `wdreg -inf <path to windrvr1281.inf> install`

     For example, if **windrvr1281.inf** and **windrvr1281.sys** are in the **d:\MyDevice** directory on the target computer, the command should be:
     `wdreg -inf d:\MyDevice\windrvr1281.inf install`

     You can find the executable of **wdreg** in the WinDriver package under the **WinDriver\util** directory. For a general description of this utility and its usage, please refer to Chapter 13.

     - **wdreg** is dependent on the **difxapi.dll** DLL.
     - **wdreg** is an interactive utility. If it fails, it will display a message instructing the user how to overcome the problem. In some cases the user may be asked to reboot the computer.

When distributing your driver, you should attempt to ensure that the installation does not overwrite a newer version of **windrvr1281.sys** with an older version of the file in Windows drivers directory (**%windir%\system32\drivers**) — for example, by configuring your installation program (if you are using one) or your INF file so that the installer automatically compares the time stamp on these two files and does not overwrite a newer version with an older one. The provided **windrvr1281.inf** file uses the `COPYFLG_NO_VERSION_DIALOG` directive, which is designed to avoid overwriting a file in the destination directory with the source file if the existing file is newer than the source file. There is also a similar `COPYFLG_OVERWRITE_OLDER_ONLY` INF directive that is designed to ensure that the source file is copied to the destination directory only if the destination file is superseded by a newer version. **Note**, however, that both of these INF directives are irrelevant to digitally signed drivers. As explained in the Microsoft *INF CopyFiles Directive* documentation — https://msdn.microsoft.com/en-us/library/ff546346%28v=vs.85%29.aspx — if a driver package is digitally signed, Windows installs the package as a whole and does not selectively omit files in the package based on other versions already present on the computer. The **windrvr1281.sys** driver provided by Jungo is digitally signed (refer to Section 15.3 for more information).

- **Install the INF file for your device** (registering your Plug-and-Play device with **windrvr1281.sys**):

  Run the utility **wdreg** with the **`install`** command to automatically install the INF file and update Windows Device Manager:
  ```
  wdreg -inf <path to your INF file> install
  ```

  You can also use the **wdreg** utility's **`preinstall`** command to pre-install an INF file for a device that is not currently connected to the PC:
  ```
  wdreg -inf <path to your INF file> preinstall
  ```

If the installation fails with an **`ERROR_FILE_NOT_FOUND`** error, inspect the Windows registry to see if the **`RunOnce`** key exists in **`HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\Windows\CurrentVersion`**. This registry key is required by Windows Plug-and-Play in order to properly install drivers using INF files. If the **`RunOnce`** key is missing, create it; then try installing the INF file again.

- **Install your Kernel PlugIn driver**: If you have created a Kernel PlugIn driver, install it by following the instructions in Section 14.2.3.

- **Install wdapi1281.dll:**
  If your hardware-control application/DLL uses **wdapi1281.dll** (as is the case for the sample and generated DriverWizard WinDriver projects), copy this DLL to the target's **%windir%\system32** directory.
  If you are distributing a 32-bit application/DLL to a target 64-bit platform [A.2], rename **wdapi1281_32.dll** in your distribution package to **wdapi1281.dll**, and copy the renamed file to the target's **%windir%\sysWOW64** directory.

If you attempt to write a 32-bit installation program that installs a 64-bit program, and therefore copies the 64-bit **wdapi1281.dll** DLL to the **%windir%\system32** directory, you may find that the file is actually copied to the 32-bit **%windir%\sysWOW64** directory. The reason for this is that Windows x64 platforms translate references to 64-bit directories from 32-bit commands into references to 32-bit directories. You can avoid the problem by using 64-bit commands to perform the necessary installation steps from your 32-bit installation program. The **system64.exe** program, provided in the **WinDriver\redist** directory of the Windows x64 WinDriver distributions, enables you to do this.

- **Install your hardware-control application/DLL**: Copy your hardware-control application/ DLL to the target and run it!

14.2.3. Installing Your Kernel PlugIn on the Target Computer

Driver installation on Windows requires administrator privileges.

If you have created a Kernel PlugIn driver, follow the additional instructions below:

1. Copy your Kernel PlugIn driver (**<KP driver name>.sys**) to Windows drivers directory on the target computer (**%windir%\system32\drivers**).

2. Use the utility **wdreg** to add your Kernel PlugIn driver to the list of device drivers Windows loads on boot. Use the following installation command:

   To install a **SYS** Kernel PlugIn Driver:
   ```
   wdreg -name <Your driver name, without the *.sys extension>
   install
   ```

   You can find the executable of **wdreg** in the WinDriver package under the **WinDriver\util** directory. For a general description of this utility and its usage, please refer to Chapter 13 (see specifically Section 13.2.3 for Kernel PlugIn installation).

14.3. Linux Driver Distribution

To distribute your driver, prepare a distribution package containing the required files — as outlined in Section 14.3.1 — and then build and install the required driver components on the target — as outlined in Sections 14.3.2–14.3.4.

- If you have renamed the WinDriver driver module [15.2], replace references to **windrvr1281** in the following instructions with the name of your renamed driver module.
- It is recommended that you supply an installation shell script to automate the build and installation processes on the target.

14.3.1. Preparing the Distribution Package

Prepare a distribution package containing the required files, as described in this section.

- If you wish to distribute drivers for both 32-bit and 64-bit target platforms, you must prepare separate distribution packages for each platform. The required files for each package are provided in the WinDriver installation directory for the respective platform.
- In the following instructions, **<source_dir>** represents the source directory from which to copy the distribution files. The default source directory is your WinDriver installation directory. However, if you have renamed the WinDriver driver module [15.2], the source directory is a directory containing modified files for compiling and installing the renamed drivers; when using DriverWizard to generate the driver code, the source directory for the renamed driver is the generated **xxx_installation** directory, where **xxx** is the name of your generated driver project (see Section 15.2.2, Step 1).

14.3.1.1. Kernel Module Components

Your WinDriver-based driver relies on the **windrvr1281.o/.ko** kernel driver module, which implements the WinDriver API. In addition, if you have created a Kernel PlugIn driver [11], the functionality of this driver is implemented in a **kp_xxx_module.o/.ko** kernel driver module (where **xxx** is your selected driver project name).

Your kernel driver modules cannot be distributed as-is; they must be recompiled on each target machine, to match the kernel version on the target. This is due to the following reason: The Linux kernel is continuously under development, and kernel data structures are subject to frequent changes. To support such a dynamic development environment, and still have kernel stability, the Linux kernel developers decided that kernel modules must be compiled with header files identical to those with which the kernel itself was compiled. They enforce this by including a version number in the kernel header files, which is checked against the version number encoded into the kernel. This forces Linux driver developers to support recompilation of their driver with the target system's kernel version.

Following is a list of the components you need to distribute to enable compilation of your kernel driver modules on the target machine.

It is recommended that you copy the files to subdirectories in the distribution directory that match the source subdirectories, such as **redist** and **include**, except where otherwise specified. If you select not do so, you will need to modify the file paths in the configuration scripts and related makefile templates, to match the location of the files in your distribution directory.

- From the <source_dir>**/include** directory, copy **windrvr.h**, **wd_ver.h**, and **windrvr_usb.h** — header files required for building the kernel modules on the target.
  Note that **windrvr_usb.h** is required also for non-USB drivers.

- From the **<WinDriver installation directory>/util** directory (or from the generated DriverWizard **xxx_installation/redist** directory), copy **wdreg** — a script for loading the WinDriver kernel driver module (see Section 13.5) — to the **redist** distribution directory.

- From the <source_dir>/**redist** directory, unless where otherwise specified, copy the following files:

  - **setup_inst_dir** — a script for installing the WinDriver driver module, using **wdreg** (see above).

  - **linux_wrappers.c/.h** — wrapper library source code files that bind the kernel module to the Linux kernel.

  - **linux_common.h** and **wdusb_interface.h** — header files required for building the kernel modules on the target.
    Note that **wdusb_interface.h** is required also for non-USB drivers.

  - The compiled object code for building the WinDriver kernel driver module —

    - **windrvr_gcc_v3.a** — for GCC v3.x.x compilation

    - **windrvr_gcc_v3_regparm.a** — for GCC v3.x.x compilation with the **regparm** flag

    - **windrvr_gcc_v2.a** — for GCC v2.x.x compilation; note that this file is not found in the 64-bit WinDriver installations, because 64-bit Linux architectures don't use GCC v2.

  - Configuration scripts and makefile templates for creating makefiles for building and installing the WinDriver kernel driver module.

    Files that include **.kbuild** in their names use **kbuild** for the driver compilation.

    - **configure** — a configuration script that uses the **makefile.in** template to create a **makefile** for building and installing the WinDriver driver module, and executes the **configure.wd** script (see below).

    - **configure.wd** — a configuration script that uses the **makefile.wd[.kbuild].in** template to create a **makefile.wd[.kbuild]** makefile for building the **windrvr1281.o/.ko** driver module.

- **makefile.in** — a template for the main **makefile** for building and installing the WinDriver kernel driver module, using **makefile.wd[.kbuild]**.

- **makefile.wd.in** and **makefile.wd.kdbuild.in** — templates for creating **makefile.wd[.kbuild]** makefiles for building and installing the **windrvr1281.o/.ko** driver module.

*If you have created a **Kernel PlugIn driver** [11] — copy the following files as well:*

- From the generated DriverWizard **xxx_installation/redist** directory (where **xxx** is the name of your driver project — see Section 15.2.2, Step 1), copy the following configuration script and makefile templates, for creating a makefile for building and installing the Kernel PlugIn driver.

If you did not generate your Kernel PlugIn driver using the DriverWizard, copy the files from your Kernel PlugIn project; the files for the **KP_PCI** sample, for example, are found in the **WinDriver/samples/pci_diag/kp_pci** directory.
Note: Before copying the files, rename them to add a ".kp" indication — as in the **xxx_installation/redist** file names listed below — in order to distinguish them from the WinDriver driver module files. You will also need to edit the file names and paths in the files, to match the structure of the distribution directory.

  - **configure.kp** — a configuration script that uses the **makefile.kp[.kbuild].in** template (see below) to create a **makefile.kp** makefile for building and installing the Kernel PlugIn driver module.

If you have renamed the WinDriver kernel module [15.2], be sure to uncomment the following line in your Kernel PlugIn configuration script (by removing the pound sign — "#"), before executing the script, in order to build the driver with the **`-DWD_DRIVER_NAME_CHANGE`** flag (see Section 15.2.2, Step 3):
`# ADDITIONAL_FLAGS="-DWD_DRIVER_NAME_CHANGE"`

  - **makefile.kp.in** and **makefile.kp.kbuild.in** — templates for creating a **makefile.kp** makefile for building and installing the Kernel PlugIn driver module.
    The makefile created from **makefile.kp.build.in** uses **kbuild** for the compilation.

- From the **<source_dir>/lib** directory, copy the compiled WinDriver-API object code —

  - **kp_wdapi1281_gcc_v3.a** — for GCC v3.x.x compilation

  - **kp_wdapi1281_gcc_v3_regparm.a** — for GCC v3.x.x compilation with the **regparm** flag

  - **kp_wdapi1281_gcc_v2.a** — for GCC v2.x.x compilation; note that this file is not found in the 64-bit WinDriver installations, because 64-bit Linux architectures don't use GCC v2.

- From the **kermode/linux/LINUX.<kernel version>.<CPU>** directory that is created when building the Kernel PlugIn driver on the development machine (see Section 12.8.2, Step 4), copy to the **lib** distribution subdirectory the compiled object code for building your Kernel PlugIn driver module (where **xxx** is the name of your Kernel PlugIn driver project) —
  - **kp_xxx_gcc_v3.a** — for GCC v3.x.x compilation
  - **kp_xxx_gcc_v3_regparm.a** — for GCC v3.x.x compilation with the **regparm** flag
  - **kp_xxx_gcc_v2.a** — for GCC v2.x.x compilation; note that this file is not found in the 64-bit WinDriver installations, because 64-bit Linux architectures don't use GCC v2.

14.3.1.2. User-Mode Hardware-Control Application or Shared Object

Copy the user-mode hardware-control application or shared object that you created with WinDriver, to the distribution package.

If your hardware-control application/shared object uses **libwdapi1281.so** — as is the case for the WinDriver samples and generated DriverWizard projects — copy this file from the <source_dir>**/lib** directory to your distribution package.
If you are distributing a 32-bit application/shared object to a target 64-bit platform [A.2] — copy **libwdapi1281_32.so** from the **WinDriver/lib** directory to your distribution package, and rename the copy to **libwdapi1281.so**.

Since your hardware-control application/shared object does not have to be matched against the Linux kernel version number, you may distribute it as a binary object (to protect your code from unauthorized copying). If you select to distribute your driver's source code, note that under the license agreement with Jungo you may not distribute the source code of the **libwdapi1281.so** shared object, or the WinDriver license string used in your code.

14.3.2. Building and Installing the WinDriver Driver Module on the Target

From the distribution package subdirectory containing the **configure** script and related build and installation files — normally the **redist** subdirectory [14.3.2] — perform the following steps to build and install the driver module on the target:

1. Generate the required makefiles:
   `$ ./configure --disable-usb-support`

- The configuration script creates a makefile based on the running kernel. You may select to use another installed kernel source, by executing the script with the **`--with-kernel-source=<path>`** option, where **`<path>`** is the full path to the kernel source directory — e.g., **/usr/src/linux**.
- If the Linux kernel version is 2.6.26 or higher, the configuration script generates makefiles that use **kbuild** to compile the kernel modules. You can force the use of **kbuild** on earlier versions of Linux, by executing the configuration script with the **`--enable-kbuild`** flag.

For a full list of the configuration script options, use the **`--help`** option:
`./configure --help`

2. Build the WinDriver driver module:
   `$ make`

   This will create a **LINUX.<kernel version>.<CPU>** directory, containing the newly compiled driver module — **windrvr1281.o/.ko**.

3. Install the **windrvr1281.o/.ko** driver module.

The following command must be executed with root privileges.

```
# make install
```

   The installation is performed using the **setup_inst_dir** script, which copies the driver module to the target's loadable kernel modules directory, and uses the **wdreg** script [13.5] to load the driver module.

4. Change the user and group IDs and give read/write permissions to the device file **/dev/windrvr1281**, depending on how you wish to allow users to access hardware through the device. Due to security reasons, by default the device file is created with permissions only for the root user. Change the permissions by modifying your **/etc/udev/permissions.d/50-udev.permissions** file. For example, add the following line to provide read and write permissions:
   `windrvr1281:root:root:0666`

Use the **wdreg** script to dynamically load the WinDriver driver module on the target after each boot [13.5]. To automate this, copy **wdreg** to the target machine, and add the following line to the target's Linux boot file (for example, **/etc/rc.local**):
`<path to wdreg> windrvr1281`

14.3.3. Building and Installing Your Kernel PlugIn Driver on the Target

If you have created a Kernel PlugIn driver [11], build and install this driver — **kp_xxx_module.o/.ko** — on the target, by performing the following steps from the distribution package subdirectory containing the **configure.kp** script and related build and installation files — normally the **redist** subdirectory [14.3.2].

1. Generate the Kernel PlugIn makefile — **makefile.kp**:
   `$ ./configure.kp`

   - The configuration script creates a makefile based on the running kernel. You may select to use another installed kernel source, by executing the script with the **`--with-kernel-source=<path>`** option, where **`<path>`** is the full path to the kernel source directory — e.g., **/usr/src/linux**.
   - If the Linux kernel version is 2.6.26 or higher, the configuration script generates makefiles that use **kbuild** to compile the kernel modules. You can force the use of **kbuild** on earlier versions of Linux, by executing the configuration script with the **`--enable-kbuild`** flag.

   For a full list of the configuration script options, use the **`--help`** option:
   `./configure.kp --help`

2. Build the Kernel PlugIn driver module:
   `$ make -f makefile.kp`

   This will create a **LINUX.<kernel version>.<CPU>.KP** directory, containing the newly compiled driver module — **kp_xxx_module.o/.ko**.

3. Install the Kernel PlugIn module.

   The following command must be executed with root privileges.

   `# make install -f makefile.kp`

To automatically load your Kernel PlugIn driver on each boot, add the following line to the target's Linux boot file (for example, **/etc/rc.local**), after the WinDriver driver module load command [13.5.1] (replace **<path to kp_xxx_module.o/.ko>** with the path to your Kernel PlugIn driver module, which is found in your **LINUX.<kernel version>.<CPU>.KP** distribution directory):
`/sbin/insmod <path to kp_xxx_module.o/.ko>`

14.3.4. Installing the User-Mode Hardware-Control Application or Shared Object

If your user-mode hardware-control application or shared object uses **libwdapi1281.so** [14.3.1.2], copy **libwdapi1281.so** from the distribution package to the target's library directory:

- **/usr/lib** — when distributing a 32-bit application/shared object to a 32-bit or 64-bit target
- **/usr/lib64** — when distributing a 64-bit application/shared object to a 64-bit target

If you decided to distribute the source code of the application/shared object [14.3.1.2], copy the source code to the target as well.

Remember that you may *not* distribute the source code of the **libwdapi1281.so** shared object or your WinDriver license string as part of the source code distribution [14.3.1.2].

Chapter 15
Driver Installation — Advanced Issues

15.1. Windows INF Files

Device information (INF) files are text files that provide information used by the Windows Plug-and-Play mechanism to install software that supports a given hardware device. INF files are required for hardware that identifies itself, such as USB and PCI. An INF file includes all necessary information about a device and the files to be installed. When hardware manufacturers introduce new products, they must create INF files to explicitly define the resources and files required for each class of device.

In some cases, the INF file for your specific device is supplied by the operating system. In other cases, you will need to create an INF file for your device. WinDriver's DriverWizard can generate a specific INF file for your device. The INF file is used to notify the operating system that WinDriver now handles the selected device.

You can use DriverWizard to generate the INF file on the development machine — as explained in Section 4.2 of the manual — and then install the INF file on any machine to which you distribute the driver, as explained in the following sections.

15.1.1. Why Should I Create an INF File?

- To bind the WinDriver kernel module to a specific PCI device.
- To override the existing driver (if any).
- To enable WinDriver applications and DriverWizard to access a PCI device.
- To enable WinDriver to obtain a Plug-and-Play representation of PCI device resources (I/O ranges, memory ranges, and interrupts).

Handling of Message-Signaled Interrupts (MSI) or Extended Message-Signaled Interrupts (MSI-X) requires specific configuration of the INF file — see further details in Section 9.2.7.1.

15.1.2. How Do I Install an INF File When No Driver Exists?

You must have administrative privileges in order to install an INF file.

You can use the **wdreg** utility with the **`install`** command to automatically install the INF file:
`wdreg -inf <path to the INF file> install`
(For more information, refer to Section 13.2.1 of the manual.)

On the development PC, you can have the INF file automatically installed when selecting to generate the INF file with DriverWizard, by checking the **Automatically Install the INF file** option in the DriverWizard's INF generation window (refer to Section 4.2).

On the development PC, you can also use the **wdreg_frontned** [13.3] utility to install/uninstall INFs and perform other advanced tasks.

It is also possible to install the INF file manually, using either of the following methods:

- Windows **Found New Hardware Wizard**: This wizard is activated when the device is plugged in or, if the device was already connected, when scanning for hardware changes from the Device Manager.
- Windows **Add/Remove Hardware Wizard**: Right-click the mouse on **My Computer**, select **Properties**, choose the **Hardware** tab and click on **Hardware Wizard...**.
- Windows **Upgrade Device Driver Wizard**: Locate the device in the **Device Manager** devices list and select the **Update Driver...** option from the right-click mouse menu or from the Device Manager's **Action** menu.

In all the manual installation methods above you will need to point Windows to the location of the relevant INF file during the installation.
We recommend using the **wdreg** utility to install the INF file automatically, instead of installing it manually.

If the installation fails with an **`ERROR_FILE_NOT_FOUND`** error, inspect the Windows registry to see if the **`RunOnce`** key exists in **`HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\Windows\CurrentVersion`**. This registry key is required by Windows Plug-and-Play in order to properly install drivers using INF files. If the **`RunOnce`** key is missing, create it; then try installing the INF file again.

15.1.3. How Do I Replace an Existing Driver Using the INF File?

You must have administrative privileges in order to replace a driver.

1. Install your INF file.

   You can use the **wdreg** utility with the **`install`** command to automatically install the INF file:
   `wdreg -inf <path to INF file> install`
   (For more information, refer to Section 13.2.1 of the manual.)

   On the development PC, you can have the INF file automatically installed when selecting to generate the INF file with DriverWizard, by checking the **Automatically Install the INF file** option in the DriverWizard's INF generation window (refer to Section 4.2).

   On the development PC, you can also use the **wdreg_frontned** [13.3] utility to install/uninstall INFs and perform other advanced tasks.

   It is also possible to install the INF file manually, using either of the following methods:

   - Windows **Found New Hardware Wizard**: This wizard is activated when the device is plugged in or, if the device was already connected, when scanning for hardware changes from the Device Manager.
   - Windows **Add/Remove Hardware Wizard**: Right-click on **My Computer**, select **Properties**, choose the **Hardware** tab and click on **Hardware Wizard...**.
   - Windows **Upgrade Device Driver Wizard**: Locate the device in the **Device Manager** devices list and select the **Update Driver...** option from the right-click mouse menu or from the Device Manager's **Action** menu.

   In the manual installation methods above you will need to point Windows to the location of the relevant INF file during the installation. If the installation wizard offers to install an INF file other than the one you have generated, select **Install one of the other drivers** and choose your specific INF file from the list.

   We recommend using the **wdreg** utility to install the INF file automatically, instead of installing it manually.

If the installation fails with an **`ERROR_FILE_NOT_FOUND`** error, inspect the Windows registry to see if the **`RunOnce`** key exists in **`HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\Windows\CurrentVersion`**. This registry key is required by Windows Plug-and-Play in order to properly install drivers using INF files. If the **`RunOnce`** key is missing, create it; then try installing the INF file again.

15.2. Renaming the WinDriver Kernel Driver

The WinDriver APIs are implemented within the WinDriver kernel driver module (**windrvr1281.sys/.dll/.o/.ko** — depending on the OS), which provides the main driver functionality and enables you to code your specific driver logic from the user mode [1.6].

On Windows and Linux you can change the name of the WinDriver kernel module to your preferred driver name, and then distribute the renamed driver instead of the default kernel module — **windrvr1281.sys/.dll/.o/.ko**. The following sections explain how to rename the driver for each of the supported operating systems.

For information on how to use the Debug Monitor to log debug messages from your renamed driver, refer to Section 6.2.1.3: Running wddebug_gui for a Renamed Driver.

A renamed WinDriver kernel driver can be installed on the same machine as the original kernel module. You can also install multiple renamed WinDriver drivers on the same machine, simultaneously.

Try to give your driver a unique name in order to avoid a potential conflict with other drivers on the target machine on which your driver will be installed.

15.2.1. Windows Driver Renaming

DriverWizard automates most of the work of renaming the Windows WinDriver kernel driver — **windrvr1281.sys**.

- When renaming the driver, the CPU architecture (32-/64-bit) of the development platform and its WinDriver installation, should match the target platform.
- Renaming the signed **windrvr1281.sys** driver nullifies its signature. In such cases you can select either to sign your new driver, or to distribute an unsigned driver. For more information on driver signing and certification, refer to Section 15.3. For guidelines for signing and certifying your renamed driver, refer to Section 15.3.2.

References to **xxx** in this section should be replaced with the name of your generated DriverWizard driver project.

To rename your Windows WinDriver kernel driver, follow these steps:

1. Use the DriverWizard utility to generate driver code for your hardware on Windows (refer to Section 4.2, Step 6), using your preferred driver name (**xxx**) as the name of the generated driver project. The generated project directory (**xxx**) will include an **xxx_installation** directory with the following files and directories:
   - **redist** directory:
     - **xxx.sys** — Your new driver, which is actually a renamed copy of the **windrvr1281.sys** driver. Note: The properties of the generated driver file (such as the file's version, company name, etc.) are identical to the properties of the original **windrvr1281.sys** driver. You can rebuild the driver with new properties using the files from the generated **xxx_installation sys** directory, as explained below.

- **xxx_driver.inf** — A modified version of the **windrvr1281.inf** file, which will be used to install your new **xxx.sys** driver.
  You can make additional modifications to this file, if you wish — namely, changing the string definitions and/or comments in the file.

- **xxx_device.inf** — A modified version of the standard generated DriverWizard INF file for your device, which registers your device with your driver (**xxx.sys**).
  You can make additional modifications to this file, if you wish, such as changing the manufacturer or driver provider strings.

- **wdapi1281.dll** — A copy of the WinDriver-API DLL. The DLL is copied here in order to simplify the driver distribution, allowing you to use the generated **xxx\redist** directory as the main installation directory for your driver, instead of the original **WinDriver\redist** directory.

- **wdreg.exe**, **wdreg_gui.exe**, and **difxapi.dll** — Copies of the CUI and GUI versions of the **wdreg** WinDriver driver installation utility, and the Driver Install Frameworks API (**DIFxAPI**) DLL required by this utility [13.2.1], (respectively). These files are copied from the **WinDriver\util** directory, to simplify the installation of the renamed driver.

- **xxx_install.bat** — An installation script that executes the **wdreg** commands for installing the **xxx_driver.inf** and **xxx_device.inf** files. This script is designed to simplify the installation of the renamed **xxx_driver.sys** driver, and the registration of your device with this driver.

- **sys** directory: This directory contains files for advanced users, who wish to change the properties of their driver file. Note: Changing the file's properties requires rebuilding of the driver module using the Windows Driver Kit (**WDK**).
  To modify the properties of your **xxx.sys** driver file:

  1. Verify that the WDK is installed on your development PC, or elsewhere on its network, and set the **BASEDIR** environment variable to point to the WDK installation directory.

  2. Modify the **xxx.rc** resources file in the generated **sys** directory in order to set different driver file properties.

  3. Rebuild the driver by running the following command:
     `ddk_make <OS> <build mode (free/checked)>`
     For example, to build a release version of the driver for Windows 7:
     `ddk_make win7 free`

- The **ddk_make.bat** utility is provided under the **WinDriver\util** directory, and should be automatically identified by Windows when running the build command. Run `ddk_make.bat` with no parameters to view the available options for this utility.
- The selected build OS must match the CPU architecture of your WinDriver installation. For example, you cannot select the 64-bit `win7_x64` OS flag when using a 32-bit WinDriver installation.

After rebuilding the **xxx.sys** driver, copy the new driver file to the generated **xxx_installation\redist** directory.

2. Verify that your user-mode application calls the `WD_DriverName`() function [B.1] with your new driver name before calling any other WinDriver function.
   Note that the sample and generated DriverWizard WinDriver applications already include a call to this function, but with the default driver name (**windrvr1281**), so all you need to do is replace the driver name that is passed to the function in the code with your new driver name.

3. Verify that your user-mode driver project is built with the `WD_DRIVER_NAME_CHANGE` preprocessor flag (e.g., `-DWD_DRIVER_NAME_CHANGE`).
   Note: The sample and generated DriverWizard WinDriver kernel projects/makefiles already set this preprocessor flag by default.

4. Install your new driver by following the instructions in Section 14.2 of the manual, using the modified files from the generated **xxx_installation** directory instead of the installation files from the original WinDriver distribution. Note that you can use the generated **xxx_install.bat** installation script (see Step 1) to simplify the installation.

15.2.2. Linux Driver Renaming

DriverWizard automates most of the work of renaming the Linux WinDriver kernel driver — **windrvr1281.o/.ko**.

References to **xxx** in this section should be replaced with the name of your generated DriverWizard driver project.

To rename your Linux WinDriver kernel driver, follow these steps:

1. Use the DriverWizard utility to generate driver code for your hardware on Linux (refer to Section 4.2, Step 6), using your preferred driver name (**xxx**) as the name of the generated driver project. The generated project directory (**xxx**) will include an **xxx_installation** directory with the following files and directories:

   - **redist** directory: This directory contains copies of the files from the original **WinDriver/redist** installation directory, but with the required modifications for building your **xxx.o/.ko** driver instead of **windrvr1281.o/.ko**.

- **lib** and **include** directories: Copies of the library and include directories from the original WinDriver distribution. These copies are created since the supported Linux WinDriver kernel driver build method relies on the existence of these directories directly under the same parent directory as the **redist** directory.

2. Verify that your user-mode application calls the `WD_DriverName()` function [B.1] with your new driver name before calling any other WinDriver function.
   Note that the sample and generated DriverWizard WinDriver applications already include a call to this function, but with the default driver name (**windrvr1281**), so all you need to do is replace the driver name that is passed to the function in the code with your new driver name.

3. Verify that your user-mode driver project is built with the `WD_DRIVER_NAME_CHANGE` preprocessor flag (`-DWD_DRIVER_NAME_CHANGE`).
   Note: The sample and generated DriverWizard WinDriver kernel projects/makefiles already set this preprocessor flag by default. If you have created a Kernel PlugIn driver [11], you will need to add this flag by uncommenting the following line in the Kernel PlugIn driver's configuration script:
   ```
   # ADDITIONAL_FLAGS="-DWD_DRIVER_NAME_CHANGE"
   ```

4. Install your new driver by following the instructions in Section 14.3 of the manual, using the modified files from the generated **xxx_installation** directory instead of the installation files from the original WinDriver distribution.
   As part of the installation, build your new kernel driver module(s) by following the instructions in Section 14.3, using the files from your new installation directory.

15.3. Windows Digital Driver Signing and Certification

15.3.1. Overview

Before distributing your driver, you may digitally sign it using Microsoft's Authenticode mechanism, and/or certify it by submitting it to Microsoft's Windows Certification Program (HLK/HCK/WLP).
Some Windows operating systems, such as Windows 7, do not require installed drivers to be digitally signed or certified. Only a popup with a warning will appear
There are, however, advantages to getting your driver digitally signed or fully certified, including the following:

- Driver installation on systems where installing unsigned drivers has been blocked
- Avoiding warnings during driver installation
- Full pre-installation of INF files [15.1] on Windows 7 and higher

64-bit versions of Windows 8 and higher require Kernel-Mode Code Signing (KMCS) of software that loads in kernel mode. This has the following implications for WinDriver-based drivers:

- Drivers that are installed via an INF file must be distributed together with a signed catalog file (see details in Section 15.3.2).

During driver development, please configure your Windows OS to temporarily allow the installation of unsigned drivers.

For more information about digital driver signing and certification, refer to the following documentation in the Microsoft Development Network (MSDN) library:

- *Driver Signing Requirements for Windows*
- *Introduction to Code Signing*
- *Digital Signatures for Kernel Modules on Windows*
  This white paper contains information about kernel-mode code signing, test signing, and disabling signature enforcement during development.
- https://msdn.microsoft.com/en-us/windows-drivers/develop/signing_a_driver

Some of the documentation may still use old terminology. For example, references to the *Windows Logo Program (**WLP**)* or to the *Windows Hardware Quality Labs (**WHQL**)* or to the *Windows Certification Program* or to the *Windows Hardware Certification Kit (**HCK**)* should be replaced with the *Windows Hardware Lab Kit (**HLK**)*, and references to the *Windows Quality Online Services (**Winqual**)* should be replaced with the *Windows Dev Center Hardware Dashboard Services (the **Hardware Dashboard**)*.

15.3.1.1. Authenticode Driver Signature

The Microsoft Authenticode mechanism verifies the authenticity of a driver's provider. It allows driver developers to include information about themselves and their code with their programs through the use of digital signatures, and informs users of the driver that the driver's publisher is participating in an infrastructure of trusted entities.
The Authenticode signature does not, however, guarantee the code's safety or functionality.

The **WinDriver\redist\windrvr1281.sys** driver has an Authenticode digital signature.

15.3.1.2. Windows Certification Program

Microsoft's Windows Certification Program (previously known as the Windows Logo Program (WLP)), lays out procedures for submitting hardware and software modules, including drivers, for Microsoft quality assurance tests. Passing the tests qualifies the hardware/software for Microsoft certification, which verifies both the driver provider's authenticity and the driver's safety and functionality.

To digitally sign and certify a device driver, a Windows Hardware Lab Kit (**HLK**) package, which includes the driver and the related hardware, should be submitted to the Windows Certification Program for testing, using the Windows Dev Center Hardware Dashboard Services (the **Hardware Dashboard**).

Jungo's professional services unit provides a complete Windows driver certification service for Jungo-based drivers. Professional engineers efficiently perform all the tests required by the Windows Certification Program, relieving customers of the expense and stress of in-house testing. Jungo prepares an HLK / HCK submission package containing the test results, and delivers the package to the customer, ready for submission to Microsoft. For more information, refer to https://www.jungo.com/st/services/windows_drivers_certification/.

For detailed information regarding Microsoft's Windows Certification Program and the certification process, refer to the MSDN *Windows Hardware Certification* page — https://msdn.microsoft.com/library/windows/hardware/gg463010.aspx — and to the documentation referenced from that page, including the MSDN *Windows Dev Center — Hardware Dashboard Services page* page — https://msdn.microsoft.com/library/windows/hardware/gg463091.

15.3.2. Driver Signing and Certification of WinDriver-Based Drivers

As indicated above [15.3.1.1], The **WinDriver\redist\windrvr1281.sys** driver has an embedded Authenticode signature. Since WinDriver's kernel module (**windrvr1281.sys**) is a generic driver, which can be used as a driver for different types of hardware devices, it cannot be submitted to Microsoft's Windows Certification Program as a standalone driver. However, once you have used WinDriver to develop a Windows driver for your selected hardware, you can submit both the hardware and driver for Microsoft certification, as explained below.

The driver certification and signature procedures — either via Authenticode or the Windows Certification Program — require the creation of a catalog file for the driver. This file is a sort of hash, which describes other files. The signed **windrvr1281.sys** driver is provided with a matching catalog file — **WinDriver\redist\windrvr1281.cat**. This file is assigned to the `CatalogFile` entry in the **windrvr1281.inf** file (provided as well in the **redist** directory). This entry is used to inform Windows of the driver's signature and the relevant catalog file during the driver's installation.

When the name, contents, or even the date of the files described in a driver's catalog file is modified, the catalog file, and consequently the driver signature associated with it, become invalid. Therefore, if you select to rename the **windrvr1281.sys** driver [15.2] and/or the related **windrvr1281.inf** file, the **windrvr1281.cat** catalog file and the related driver signature will become invalid.

In addition, when using WinDriver to develop a driver for your Plug-and-Play device, you normally also create a device-specific INF file that registers your device to work with the **windrvr1281.sys** driver module (or a renamed version of this driver). Since this INF file is created at your site, for your specific hardware, it is not referenced from the **windrvr1281.cat** catalog file and cannot be signed by Jungo a priori.

When renaming **windrvr1281.sys** and/or creating a device-specific INF file for your device, you have two alternative options regarding your driver's digital signing:

- Do not digitally sign your driver. If you select this option, remove or comment-out the reference to the **windrvr1281.cat** file from the **windrvr1281.inf** file (or your renamed version of this file).

- Submit your driver to the Windows Certification Program, or have it Authenticode signed. Note that while renaming **WinDriver\redist\windrvr1281.sys** nullifies the driver's digital signature, the driver is still compliant with the certification requirements of the Windows Certification Program.

  To digitally sign/certify your driver, follow these steps:

  - Create a new catalog file for your driver, as explained in the Windows Certification Program documentation. The new file should reference both **windrvr1281.sys** (or your renamed driver) and any INF files used in your driver's installation.

  - Assign the name of your new catalog file to the `CatalogFile` entry in your driver's INF file(s). (You can either change the `CatalogFile` entry in the **windrvr1281.inf** file to refer to your new catalog file, and add a similar entry in your device-specific INF file; or incorporate both **windrvr1281.inf** and your device INF file into a single INF file that contains such a `CatalogFile` entry).

  - Submit your driver to Microsoft's Windows Certification Program or for an Authenticode signature. If you wish to submit your driver to the Windows Certification Program, refer to the additional guidelines in Section 15.3.2.1.

    Note that many WinDriver customers have already successfully digitally signed and certified their WinDriver-based drivers.

15.3.2.1. HCK Test Notes

As indicated in Microsoft's documentation, before submitting the driver for testing and certification you need to download the Windows Hardware Certification Kit (**HCK**), and run the relevant tests for your hardware/software. After you have verified that you can successfully pass the HCK tests, create the required logs package and proceed according to Microsoft's documentation. For more information, refer to the MSDN *Windows Hardware Certification Kit (HCK)* page — https://msdn.microsoft.com/library/windows/hardware/hh833788.

Appendix A
64-Bit Operating Systems Support

A.1. Supported 64-Bit Architectures

WinDriver supports the following 64-bit platforms:

- Linux AMD64 or Intel EM64T (**x86_64**).
  For a full list of the Linux platforms supported by WinDriver, refer to Section 3.1.3.

- Windows AMD64 or Intel EM64T (**x64**).
  For a full list of the Windows platforms supported by WinDriver, refer to Section 3.1.1.

The project or makefile for a 64-bit driver project must include the **`KERNEL_64BIT`** preprocessor definition. In the makefiles, the definition is added using the `-D` flag: `-DKERNEL_64BIT`.
The sample and wizard-generated Linux and Windows GCC makefiles and the Windows MS Visual Studio projects, in the 64-bit WinDriver toolkit, already include this definition.

For information regarding performing 64-bit data transfers with WinDriver, including on 32-bit platforms, refer to Section 10.2.3.

A.2. Support for 32-Bit Applications on 64-Bit Windows and Linux Platforms

By default, applications created using the 64-bit versions of WinDriver are 64-bit applications. Such applications are more efficient than 32-bit applications. However, you can also use the 64-bit WinDriver versions to create 32-bit applications that will run on the supported Windows and Linux 64-bit platforms [A.1].

In the following documentation, **<WD64>** signifies the path to a 64-bit WinDriver installation directory for your target operating system, and **<WD32>** signifies the path to a 32-bit WinDriver installation directory for the same operating system.

To create a 32-bit application for 64-bit Windows or Linux platforms, using the 64-bit version of WinDriver, do the following:

1. Create a WinDriver application, as outlined in this manual (e.g., by generating code with DriverWizard, or using one of the WinDriver samples).

2. Build the application with an appropriate 32-bit compiler for your target OS, using the following configuration:

   - Add a **`KERNEL_64BIT`** preprocessor definition to your project or makefile.

     
     In the makefiles, the definition is added using the `-D` flag: `-DKERNEL_64BIT`.

     The sample and wizard-generated Linux and Windows GCC makefiles and the Windows MS Visual Studio projects, in the 64-bit WinDriver toolkit, already include this definition.

   - Link the application with the specific version of the WinDriver-API library/ shared object for 32-bit applications executed on 64-bit platforms — **<WD64>\lib\amd64\x86\wdapi1281.lib** on Windows / **<WD64>/lib/libwdapi1281_32.so** on Linux.

     The sample and wizard-generated project and make files for 32-bit applications in the 64-bit WinDriver toolkit already link to the correct library:
     On Windows, the MS Visual Studio project files and Windows GCC makefiles are defined to link with **<WD64>\lib\amd64\x86\wdapi1281.lib**.
     On Linux, the installation of the 64-bit WinDriver toolkit on the development machine creates a **libwdapi1281.so** symbolic link in the **/usr/lib** directory — which links to **<WD64>/lib/libwdapi1281_32.so** — and in the **/usr/lib64** directory — which links to **<WD64>/lib/libwdapi1281.so** (the 64-bit version of this shared object).
     The sample and wizard-generated WinDriver makefiles rely on these symbolic links to link with the appropriate shared object, depending on whether the code is compiled using a 32-bit or 64-bit compiler.

- When distributing your application to target 64-bit platforms, you need to provide with it the WinDriver-API DLL/shared object for 32-bit applications executed on 64-bit platforms — **<WD64>\redist\wdapi1281_32.dll** on Windows / **<WD64>/lib/libwdapi1281_32.so** on Linux. Before distributing this file, rename the copy of the file in your distribution package by removing the **_32** portion. The installation on the target should copy the renamed DLL/shared object to the relevant OS directory — **\%windir%\sysWOW64** on Windows or **/usr/lib** on Linux. All other distribution files are the same as for any other 64-bit WinDriver driver distribution, as detailed in Chapter 14.

- An application created using the method described in this section will *not* work on 32-bit platforms. A WinDriver application for 32-bit platforms needs to be compiled without the `KERNEL_64BIT` definition; it needs to be linked with the standard 32-bit version of the WinDriver-API library/shared object from the 32-bit WinDriver installation (**<WD32>\lib\x86\wdapi1281.lib** on Windows / **<WD32>/lib/libwdapi1281.so** on Linux); and it should be distributed with the standard 32-bit WinDriver-API DLL/shared object (**<WD32>\redist\wdapi1281.dll** on Windows / **<WD32>/lib/libwdapi1281.so** on Linux) and any other required 32-bit distribution file, as outlined in Chapter 14.

A.3. 64-Bit and 32-Bit Data Types

In general, DWORD is unsigned long. While any 32-bit compiler treats this type as 32 bits wide, 64-bit compilers treat this type differently. With Windows 64-bit compilers the size of this type is still 32 bits. However, with UNIX 64-bit compilers (e.g., GCC, SUN Forte) the size of this type is 64 bits. In order to avoid compiler dependency issues, use the UINT32 and UINT64 cross-platform types when you want to refer to a 32-bit or 64-bit address, respectively.

Appendix B
API Reference

This function reference is C oriented. The WinDriver C# APIs have been implemented as closely as possible to the C APIs, therefore .NET programmers can also use this reference to better understand the WinDriver APIs for their selected development language. For the exact API implementation and usage examples for your selected language, refer to the WinDriver .NET source code.

B.1. WD_DriverName

Purpose

Sets the name of the WinDriver kernel module, which will be used by the calling application.

- The default driver name, which is used if the function is not called, is **windrvr1281**.
- This function must be called once, and only once, from the beginning of your application, before calling any other WinDriver function (including `WD_Open`() / `WDC_DriverOpen`() / `WDC_xxxDeviceOpen`()), as demonstrated in the sample and generated DriverWizard WinDriver applications, which include a call to this function with the default driver name — **windrvr1281**.
- On Windows and Linux, if you select to modify the name of the WinDriver kernel module (**windrvr1281.sys/.dll/.o/.ko**), as explained in Section 15.2, you must ensure that your application calls `WD_DriverName`() with your new driver name.
- In order to use the `WD_DriverName`() function, your user-mode driver project must be built with `WD_DRIVER_NAME_CHANGE` preprocessor flag (e.g.: `-DWD_DRIVER_NAME_CHANGE` — for MS Visual Studio, Windows GCC, and GCC).
  The sample and generated DriverWizard Windows and Linux WinDriver projects/makefiles already set this preprocessor flag.

Prototype

```
const char* DLLCALLCONV WD_DriverName(const char* sName);
```

Parameters

Name	Type	Input/Output
sName	const char*	Input

Description

Name	Description
sName	The name of the WinDriver kernel module to be used by the application. NOTE: The driver name should be indicated without the driver file's extension. For example, use **windrvr1281**, not **windrvr1281.sys** or **windrvr1281.o**.

Return Value

Returns the selected driver name on success; returns NULL on failure (e.g., if the function is called twice from the same application)long.

Remarks

The ability to rename the WinDriver kernel module is supported on Windows and Linux, as explained in Section 15.2.

B.2. WDC Library Overview

The *"WinDriver Card"* — **WDC** — API provides convenient user-mode wrappers to the basic WinDriver PCI/ISA `WD_xxx` API, which is described in the **WinDriver PCI Low-Level API Reference**.

The WDC wrappers are designed to simplify the usage of WinDriver for communicating with PCI/ISA devices. While you can still use the basic `WD_xxx` PCI/ISA WinDriver API from your code, we recommend that you refrain from doing so and use the high-level WDC API instead.

NOTE: Most of the WDC API can be used both from the user mode and from the kernel mode (from a Kernel PlugIn driver [11]).

The generated DriverWizard PCI/ISA diagnostics driver code, as well as the PLX sample code, and the **pci_diag**, Kernel PlugIn **pci_diag** and **pci_dump** samples, for example, utilize the WDC API.

The WDC API is part of **wdapi1281** DLL/shared object:
WinDriver\redist\wdapi1281.dll (Windows) / **WinDriver/lib/libwdapi1281.so** (Linux).
The source code for the WDC API is found in the **WinDriver/src/wdapi** directory.

The WDC interface is provided in the **wdc_lib.h** and **wdc_defs.h** header files (both found under the **WinDriver/includes** directory).

- [**wdc_lib.h**] declares the "high-level" WDC API (type definitions, function declarations, etc.).
- [**wdc_defs.h**] declares the "low-level" WDC API. This file includes definitions and type information that is encapsulated by the high-level **wdc_lib.h** file.

The WinDriver PCI/ISA samples and generated DriverWizard code that utilize the WDC API, for example, consist of a "library" for the specific device, and a diagnostics application that uses it. The high-level diagnostics code only utilizes the **wdc_lib.h** API, while the library code also uses the low-level API from the **wdc_defs.h** file, thus maintaining the desired level of encapsulation.

The following sections describe the WDC high-level [B.3] and low-level [B.4] API.

B.3. WDC High-Level API

This section describes the WDC API defined in the **WinDriver/include/wdc_lib.h** header file.

B.3.1. Structures, Types and General Definitions

B.3.1.1. WDC_DEVICE_HANDLE

Handle to a WDC device information structure [B.4.2].

```
typedef void * WDC_DEVICE_HANDLE;
```

B.3.1.2. WDC_DRV_OPEN_OPTIONS Definitions

```
typedef DWORD WDC_DRV_OPEN_OPTIONS;
```

Preprocessor definitions of flags that describe tasks to be performed when opening a handle to the WDC library (see `WDC_DriverOpen()` [B.3.2]).

Name	Description
WDC_DRV_OPEN_CHECK_VER	Compare the version of the WinDriver source files used by the code with the version of the loaded WinDriver kernel
WDC_DRV_OPEN_REG_LIC	Register a WinDriver license registration string

The following preprocessor definitions provide convenient WDC driver open options, which can be passed to `WDC_DriverOpen()` [B.3.2]:

Name	Description
WDC_DRV_OPEN_BASIC	Instructs `WDC_DriverOpen()` [B.3.2] to perform only the basic WDC open tasks, mainly open a handle to WinDriver's kernel module. NOTE: The value of this option is zero (<=> no driver open flags), therefore this option cannot be combined with any of the other WDC driver open options.
WDC_DRV_OPEN_KP	Convenience option when calling `WDC_DriverOpen()` [B.3.2] from the Kernel PlugIn. This option is equivalent to setting the `WDC_DRV_OPEN_BASIC` flag, which is the recommended option to set when opening a handle to the WDC library from the Kernel PlugIn.
WDC_DRV_OPEN_ALL	A convenience mask of all the basic WDC driver open flags — `WDC_DRV_OPEN_CHECK_VER` and `WDC_DRV_OPEN_REG_REG_LIC`. (The basic functionality of opening a handle to WinDriver's kernel module is always performed by `WDC_DriverOpen()` [B.3.2], so there is no need to also set the `WDC_DRV_OPEN_BASIC` flag).
WDC_DRV_OPEN_DEFAULT	Use the default WDC open options: • For **user-mode** applications: equivalent to setting `WDC_DRV_OPEN_ALL` ; • For a **Kernel PlugIn**: equivalent to setting `WDC_DRV_OPEN_KP`

B.3.1.3. WDC_DIRECTION Enumeration

Enumeration of a device's address/register access directions.

Enum Value	Description
WDC_READ	Read from the address
WDC_WRITE	Write to the address
WDC_READ_WRITE	Read from the address or write to it. This value is used, for example, in the WinDriver samples and generated DriverWizard diagnostics code in order to describe a register's access mode, indicating that the register can either be read from or written to.

B.3.1.4. WDC_ADDR_MODE Enumeration

Enumeration of memory or I/O addresses/registers read/write modes.
The enumeration values are used to determine whether a memory or I/O address/register is read/written in multiples of 8, 16, 32 or 64 bits (i.e., 1, 2, 4 or 8 bytes).

Enum Value	Description
WDC_MODE_8	8 bits (1 byte) mode
WDC_MODE_16	16 bits (2 bytes) mode
WDC_MODE_32	32 bits (4 bytes) mode
WDC_MODE_64	64 bits (8 bytes) mode

B.3.1.5. WDC_ADDR_RW_OPTIONS Enumeration

Enumeration of flags that are used to determine how a memory or I/O address will be read/written.

Enum Value	Description
WDC_ADDR_RW_DEFAULT	Use the default read/write options: memory addresses are accessed directly from the calling process; block transfers are performed from subsequent addresses (automatic increment). NOTE: The value of this flag is zero (<=> no read/write flags), therefore it **can not** be combined in a bit-mask with any of the other read/write options flags. This option is used by the `WDC_ReadAddr8/16/32/64`() [B.3.26] and `WDC_WriteAddr8/16/32/64`() [B.3.27] functions.
WDC_ADDR_RW_NO_AUTOINC	Do no automatically increment the read/write address in block transfers, i.e., hold the device address constant while reading/writing a block of memory or I/O addresses (relevant only for block (string) transfers).

B.3.1.6. WDC_ADDR_SIZE Definitions

```
typedef DWORD WDC_ADDR_SIZE;
```

Preprocessor definitions that depict memory or I/O address/register sizes.

Name	Description
WDC_SIZE_8	8 bits (1 byte)
WDC_SIZE_16	16 bits (2 bytes)
WDC_SIZE_32	32 bits (4 bytes)
WDC_SIZE_64	64 bits (8 bytes)

B.3.1.7. WDC_SLEEP_OPTIONS Definitions

```
typedef DWORD WDC_SLEEP_OPTIONS;
```

Preprocessor definitions that depict the sleep options that can be passed to `WDC_Sleep`() [B.3.61].

Name	Description
WDC_SLEEP_BUSY	Delay execution by consuming CPU cycles (busy sleep)
WDC_SLEEP_NON_BUSY	Delay execution without consuming CPU cycles (non-busy sleep). Note: The accuracy of non-busy sleep is machine-dependent and cannot be guaranteed for short sleep intervals (< 1 millisecond).

B.3.1.8. WDC_DBG_OPTIONS Definitions

```
typedef DWORD WDC_DBG_OPTIONS;
```

Preprocessor definitions that depict the possible debug options for the WDC library, which are passed to `WDC_SetDebugOptions`() [B.3.55].

The following flags determine the output file for the WDC library's debug messages:

Name	Description
WDC_DBG_OUT_DBM	Send debug messages from the WDC library to the Debug Monitor [6.2]
WDC_DBG_OUT_FILE	Send debug messages from the WDC library to a debug file. By default, the debug file will be **stderr**, unless a different file is set in the **`sDbgFile`** parameter of the `WDC_SetDebugOptions`() function [B.3.55]. This option is only supported from the user mode (as opposed to the Kernel PlugIn).

The following flags determine the debug level — i.e., what type of WDC debug messages to display, if at all:

Name	Description
WDC_DBG_LEVEL_ERR	Display only WDC error debug messages
WDC_DBG_LEVEL_TRACE	Display both error and trace WDC debug messages
WDC_DBG_NONE	Do not display WDC debug messages

The following preprocessor definitions provide convenient debug flags combinations, which can be passed to `WDC_SetDebugOptions`() [B.3.55]:

• User-mode and Kernel PlugIn convenience debug options:

Name	Description
WDC_DBG_DEFAULT	`WDC_DBG_OUT_DBM | WDC_DBG_LEVEL_TRACE`: Use the default debug options — send WDC error and trace messages to the Debug Monitor [6.2].
WDC_DBG_DBM_ERR	`WDC_DBG_OUT_DBM | WDC_DBG_LEVEL_ERR`: Send WDC error debug messages to the Debug Monitor [6.2].
WDC_DBG_DBM_TRACE	`WDC_DBG_OUT_DBM | WDC_DBG_LEVEL_TRACE`: Send WDC error and trace debug messages to the Debug Monitor [6.2].
WDC_DBG_FULL	Full WDC debugging: • From the **user mode**: `WDC_DBG_OUT_DBM | WDC_DBG_OUT_FILE | WDC_DBG_LEVEL_TRACE`: Send WDC error and trace debug messages both to the Debug Monitor [6.2] and to a debug output file (default file: **stderr**) • From the **Kernel PlugIn**: `WDC_DBG_OUT_DBM | WDC_DBG_LEVEL_TRACE`: Send WDC error and trace messages to the Debug Monitor [6.2]

• User-mode only convenience debug options:

Name	Description
WDC_DBG_FILE_ERR	`WDC_DBG_OUT_FILE | WDC_DBG_LEVEL_ERR`: Send WDC error debug messages to a debug file (default file: **stderr**)
WDC_DBG_FILE_TRACE	`WDC_DBG_OUT_FILE | WDC_DBG_LEVEL_TRACE`: Send WDC error and trace debug messages to a debug file (default file: **stderr**)
WDC_DBG_DBM_FILE_ERR	`WDC_DBG_OUT_DBM | WDC_DBG_OUT_FILE | WDC_DBG_LEVEL_ERR`: Send WDC error debug messages both to the Debug Monitor [6.2] and to a debug file (default file: **stderr**)
WDC_DBG_DBM_FILE_TRACE	`WDC_DBG_OUT_DBM | WDC_DBG_OUT_FILE | WDC_DBG_LEVEL_TRACE`: Send WDC error and trace debug messages both to the Debug Monitor [6.2] and to a debug file (default file: **stderr**)

B.3.1.9. WDC_PCI_SCAN_RESULT Structure

Structure for holding the results of a PCI bus scan (see `WDC_PciScanDevices`() [B.3.4]).

Field	Type	Description
dwNumDevices	DWORD	Number of devices found on the PCI bus that match the search criteria (vendor & device IDs)
deviceId	WD_PCI_ID[WD_PCI_CARDS]	Array of matching vendor and device IDs found on the PCI bus [B.7.3]
deviceSlot	WD_PCI_SLOT[WD_PCI_CARDS]	Array of PCI device location information structures [B.7.4] for the detected devices matching the search criteria

B.3.1.10. WDC_PCI_SCAN_CAPS_RESULT Structure

Structure for holding the results of a PCI capabilities scan (see `WDC_PciScanCaps`() [B.3.7] and `WDC_PciScanExtCaps`() [B.3.9]).

Field	Type	Description
dwNumCaps	DWORD	Number of capabilities found that match the search criteria (capability ID and capabilities group — basic [B.3.7] or extended [B.3.9])
pciCaps	WD_PCI_CAP[WD_PCI_MAX_CAPS]	Array of matching PCI capabilities [B.7.5]

B.3.2. WDC_DriverOpen()

Purpose

Opens and stores a handle to WinDriver's kernel module and initializes the WDC library according to the open options passed to it.
This function should be called once before calling any other WDC API.

Prototype

```
DWORD DLLCALLCONV WDC_DriverOpen(
    WDC_DRV_OPEN_OPTIONS openOptions,
    const CHAR *sLicense);
```

Parameters

Name	Type	Input/Output
openOptions	WDC_DRV_OPEN_OPTIONS	Input
sLicense	const CHAR*	Input

Description

Name	Description
openOptions	A mask of any of the supported open flags [B.3.1.2], which determines the initialization actions that will be performed by the function.
sLicense	WinDriver license registration string. This argument is ignored if the `WDC_DRV_OPEN_REG_LIC` flag is not [B.3.1.2] set in the **`openOptions`** argument. If this parameter is a `NULL` pointer or an empty string, the function will attempt to register the demo WinDriver evaluation license. Therefore, when evaluating WinDriver pass `NULL` as this parameter. After registering your WinDriver toolkit, modify the code to pass your WinDriver license registration string.

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.3.3. WDC_DriverClose()

Purpose

Closes the WDC WinDriver handle (acquired and stored by a previous call to `WDC_DriverOpen`() [B.3.2]) and uninitializes the WDC library.

Every `WDC_DriverOpen`() call should have a matching `WDC_DriverClose`() call, which should be issued when you no longer need to use the WDC library.

Prototype

```
DWORD DLLCALLCONV WDC_DriverClose(void);
```

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.3.4. WDC_PciScanDevices()

Purpose

Scans the PCI bus for all devices with the specified vendor and device ID combination and returns information regarding the matching devices that were found and their locations. The function performs the scan by iterating through all possible PCI buses on the host platform, then through all possible PCI slots, and then through all possible PCI functions.

Scan-By-Topology Note
On rare occasions, as a result of malfunctioning hardware, the scan information may contain repeated instances of the same device. As a result, the function might fail to return valid scan data. In such cases, if you cannot remove the malfunctioning device, you can scan the PCI bus using `WDC_PciScanDevicesByTopology`() [B.3.5] or `WDC_PciScanRegisteredDevices`() [B.3.6].

Prototype

```
DWORD DLLCALLCONV WDC_PciScanDevices(
    DWORD dwVendorId,
    DWORD dwDeviceId,
    WDC_PCI_SCAN_RESULT *pPciScanResult);
```

Parameters

Name	Type	Input/Output
dwVendorId	DWORD	Input
dwDeviceId	DWORD	Input
pPciScanResult	WDC_PCI_SCAN_RESULT*	Output

Description

Name	Description
dwVendorId	Vendor ID to search for, or 0 to search for all vendor IDs
dwDeviceId	Device ID to search for, or 0 to search for all device IDs
pPciScanResult	A pointer to a structure that will be updated by the function with the results of the PCI bus scan [B.3.1.9]

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

Remarks

- If you set both the vendor and device IDs to zero, the function will return information regarding all connected PCI devices.

B.3.5. WDC_PciScanDevicesByTopology()

Purpose

Scans the PCI bus for all devices with the specified vendor and device ID combination and returns information regarding the matching devices that were found and their locations. The function performs the scan by topology — i.e., for each located bridge the function scans the connected devices and functions reported by the bridge, and only then proceeds to scan the next bridge.

- In the case of multiple host controllers, `WDC_PciScanDevicesByTopology`() will perform the scan only for the first host controller.
- By default, use `WDC_PciScanDevices`() [B.3.4] to scan the PCI bus, unless a device malfunction intererferes — refer to the note in the description of `PciScanDevices`().

Prototype

```
DWORD DLLCALLCONV WDC_PciScanDevicesByTopology(
    DWORD dwVendorId,
    DWORD dwDeviceId,
    WDC_PCI_SCAN_RESULT *pPciScanResult);
```

Parameters

Name	Type	Input/Output
dwVendorId	DWORD	Input
dwDeviceId	DWORD	Input
pPciScanResult	WDC_PCI_SCAN_RESULT*	Output

Description

Name	Description
dwVendorId	Vendor ID to search for, or 0 to search for all vendor IDs
dwDeviceId	Device ID to search for, or 0 to search for all device IDs
pPciScanResult	A pointer to a structure that will be updated by the function with the results of the PCI bus scan [B.3.1.9]

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

Remarks

- If you set both the vendor and device IDs to zero, the function will return information regarding all connected PCI devices.

B.3.6. WDC_PciScanRegisteredDevices()

Purpose

Scans the PCI bus for all devices with the specified vendor and device ID combination that have been registered to work with WinDriver, and returns information regarding the matching devices that were found and their locations. The function performs the scan by iterating through all possible PCI buses on the host platform, then through all possible PCI slots, and then through all possible PCI functions.

- By default, use `WDC_PciScanDevices()` [B.3.4] to scan the PCI bus, unless a device malfunction intererferes — refer to the note in the description of `PciScanDevices()`.

Prototype

```
DWORD DLLCALLCONV WDC_PciScanRegisteredDevices(
    DWORD dwVendorId,
    DWORD dwDeviceId,
    WDC_PCI_SCAN_RESULT *pPciScanResult);
```

Parameters

Name	Type	Input/Output
dwVendorId	DWORD	Input
dwDeviceId	DWORD	Input
pPciScanResult	WDC_PCI_SCAN_RESULT*	Output

Description

Name	Description
dwVendorId	Vendor ID to search for, or 0 to search for all vendor IDs
dwDeviceId	Device ID to search for, or 0 to search for all device IDs
pPciScanResult	A pointer to a structure that will be updated by the function with the results of the PCI bus scan [B.3.1.9]

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

Remarks

- If you set both the vendor and device IDs to zero, the function will return information regarding all connected PCI devices that are registered with WinDriver.

B.3.7. WDC_PciScanCaps()

Purpose

Scans the basic PCI capabilities of the given device for the specified capability (or for all capabilities).

Prototype

```
DWORD DLLCALLCONV WDC_PciScanCaps(
    WDC_DEVICE_HANDLE hDev,
    DWORD dwCapId,
    WDC_PCI_SCAN_CAPS_RESULT *pScanCapsResult);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
dwCapId	DWORD	Input
pScanCapsResult	WDC_PCI_SCAN_CAPS_RESULT*	Output

Description

Name	Description
hDev	Handle to a WDC PCI device structure, returned by `WDC_PciDeviceOpen()` [B.3.17]
dwCapId	ID of the basic PCI capability for which to search, or `WD_PCI_CAP_ID_ALL` to search for all basic PCI capabilities
pScanCapsResult	A pointer to a structure that will be updated by the function with the results of the basic PCI capabilities scan [B.3.1.10]

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.3.8. WDC_PciScanCapsBySlot()

Purpose

Scans the basic PCI capabilities of the given device for the specified capability (or for all capabilities).

Prototype

```
DWORD DLLCALLCONV WDC_PciScanCapsBySlot(
    WD_PCI_SLOT *pSlot,
    DWORD dwCapId,
    WDC_PCI_SCAN_CAPS_RESULT *pScanCapsResult);
```

Parameters

Name	Type	Input/Output
pSlot	WD_PCI_SLOT*	Input
dwCapId	DWORD	Input
pScanCapsResult	WDC_PCI_SCAN_CAPS_RESULT*	Output

Description

Name	Description
pSlot	Pointer to a PCI device location information structure [B.7.4], which can be acquired by calling `WDC_PciScanDevices`() [B.3.4]
dwCapId	ID of the basic PCI capability for which to search, or `WD_PCI_CAP_ID_ALL` to search for all basic PCI capabilities
pScanCapsResult	A pointer to a structure that will be updated by the function with the results of the basic PCI capabilities scan [B.3.1.10]

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.3.9. WDC_PciScanExtCaps()

Purpose

Scans the extended (PCI Express) PCI capabilities of the given device for the specified capability (or for all capabilities).

Prototype

```
DWORD DLLCALLCONV WDC_PciScanExtCaps(
    WDC_DEVICE_HANDLE hDev,
    DWORD dwCapId,
    WDC_PCI_SCAN_CAPS_RESULT *pScanCapsResult);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
dwCapId	DWORD	Input
pScanCapsResult	WDC_PCI_SCAN_CAPS_RESULT*	Output

Description

Name	Description
hDev	Handle to a WDC PCI device structure, returned by `WDC_PciDeviceOpen`() [B.3.17]
dwCapId	ID of the extended PCI capability for which to search, or `WD_PCI_CAP_ID_ALL` to search for all extended PCI capabilities
pScanCapsResult	A pointer to a structure that will be updated by the function with the results of the extended (PCI Express) PCI capabilities scan [B.3.1.10]

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.3.10. WDC_PciGetExpressGen()

Purpose

Retrieves the PCI Express generation of a device.

Prototype

```
DWORD DLLCALLCONV WDC_PciGetExpressGen(
    WDC_DEVICE_HANDLE hDev);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input

Description

Name	Description
hDev	Handle to a WDC PCI device structure, returned by `WDC_PciDeviceOpen`() [B.3.17]

Return Value

Returns 0 if device is not a PCI Express device, otherwise returns the PCI Express generation of the device;

B.3.11. WDC_PciGetExpressGenBySlot()

Purpose

Retrieves the PCI Express generation of a device.

Prototype

```
DWORD DLLCALLCONV WDC_PciGetExpressGenBySlot(
    WD_PCI_SLOT *pPciSlot);
```

Parameters

Name	Type	Input/Output
pPciSlot	WD_PCI_SLOT*	Input

Description

Name	Description
pPciSlot	Pointer to a PCI device location information structure [B.7.4], which can be acquired by calling `WDC_PciScanDevices`() [B.3.4]

Return Value

Returns 0 if device is not a PCI Express device, otherwise returns the PCI Express generation of the device;

B.3.12. WDC_PciGetExpressOffset()

Purpose

Retrieves the PCI Express configuration registers' offset in the device's configuration space. This offset varies between devices and needs to be added to any extended configuration space register's fixed address. The fixed addresses were defined in the PCI Express Base Specification.

Prototype

```
DWORD DLLCALLCONV WDC_PciGetExpressOffset(
    WDC_DEVICE_HANDLE hDev,
    DWORD *pdwOffset);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
pdwOffset	DWORD*	Output

Description

Name	Description
hDev	Handle to a WDC PCI device structure, returned by `WDC_PciDeviceOpen()` [B.3.17]
pdwOffset	Pointer to the DWORD where the offset value will be written.

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.3.13. WDC_PciGetHeaderType()

Purpose

Retrieves the PCI device's configuration space header type. The header type is hardware dependent and determines how the configuration space is arranged.

Prototype

```
DWORD DLLCALLCONV WDC_PciGetHeaderType(
    WDC_DEVICE_HANDLE hDev,
    WDC_PCI_HEADER_TYPE *header_type);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
header_type	WDC_PCI_HEADER_TYPE *	Output

Description

Name	Description
hDev	Handle to a WDC PCI device structure, returned by `WDC_PciDeviceOpen`() [B.3.17]
header_type	A pointer to the structure where the header type will be updated. WDC_PCI_HEADER_TYPE definition and available values can be seen in **WinDriver/include/pci_regs.h**

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.3.14. PciConfRegData2Str()

Purpose

Reads data from a PCI device's configuration space and parses the data to a string, if such a parsing is available. The parsing is based upon information obtained from the official PCI Specification, 3rd Generation.

Prototype

```
DWORD DLLCALLCONV PciConfRegData2Str(
   WDC_DEVICE_HANDLE hDev,
   DWORD dwOffset,
   PCHAR pBuf,
   DWORD dwInLen,
   DWORD *pdwOutLen);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
dwOffset	DWORD	Input
pBuf	PCHAR	Output
dwInLen	DWORD	Input
pdwOutLen	DWORD *	Output

Description

Name	Description
hDev	Handle to a WDC PCI device structure, returned by `WDC_PciDeviceOpen()` [B.3.17]
dwOffset	Offset of a register in the configuration space to be read and parsed to a string, if a parsing is available.
pBuf	A pointer to a user preallocated buffer to be filled by the function. The buffer will not be filled if no parsing is available.
dwInLen	Size of the user preallocated buffer.
pdwOutLen	A pointer to a DWORD which will hold the actual length of the string the function wrote to the buffer. If the buffer is too small for the text written by the function then the text will be truncated. We recommend preallocating a 1024 byte buffer to avoid any truncation.

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.3.15. PciExpressConfRegData2Str()

Purpose

Reads data from a PCI Express device's extended configuration space and parses the data to a string, if such a parsing is available. The parsing is based upon information obtained from the official PCI Specification, 3rd Generation.

Prototype

```
DWORD DLLCALLCONV PciExpressConfRegData2Str(
   WDC_DEVICE_HANDLE hDev,
   DWORD dwOffset,
   PCHAR pBuf,
   DWORD dwInLen,
   DWORD *pdwOutLen);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
dwOffset	DWORD	Input
pBuf	PCHAR	Output
dwInLen	DWORD	Input
pdwOutLen	DWORD *	Output

Description

Name	Description
hDev	Handle to a WDC PCI device structure, returned by `WDC_PciDeviceOpen`() [B.3.17]
dwOffset	Offset of a register in the configuration space to be read and parsed to a string, if a parsing is available. Offset should be the sum of the value obtained from WDC_PciGetExpressOffset() `WDC_PciGetExpressOffset`() [B.3.12] and the desired PCI Express offset.
pBuf	A pointer to a user preallocated buffer to be filled by the function. The buffer will not be filled if no parsing is available.
dwInLen	Size of the user preallocated buffer.
pdwOutLen	A pointer to a DWORD which will hold the actual length of the string the function wrote to the buffer. If the buffer is too small for the text written by the function then the text will be truncated. We recommend preallocating a 1024 byte buffer to avoid any truncation.

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.3.16. WDC_PciGetDeviceInfo()

Purpose

Retrieves a PCI device's resources information (memory and I/O ranges and interrupt information).

Prototype

```
DWORD DLLCALLCONV WDC_PciGetDeviceInfo(
    WD_PCI_CARD_INFO *pDeviceInfo);
```

Parameters

Name	Type	Input/Output
pDeviceInfo	WD_PCI_CARD_INFO*	Input/Output
• pciSlot	WD_PCI_SLOT	Input
• Card	WD_CARD	Output

Description

Name	Description
pDeviceInfo	Pointer to a PCI device information structure [B.7.8]

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

Remarks

- The resources information is obtained from the operating system's Plug-and-Play manager, unless the information is not available, in which case it is read directly from the PCI configuration registers.
  Note: On Windows, you must install an **INF file** file, which registers your device with WinDriver, before calling this function (see Section 15.1 regarding creation of INF files with WinDriver).

- If the interrupt request (IRQ) number is obtained from the Plug-and-Play manager, it is mapped, and therefore may differ from the physical IRQ number.

B.3.17. WDC_PciDeviceOpen()

Purpose

Allocates and initializes a WDC PCI device structure, registers the device with WinDriver, and returns a handle to the device.

This function

- Verifies that none of the registered device resources (set in **`pDeviceInfo->Card.Item`**) are already locked for exclusive use.

  A resource can be locked for exclusive use by setting the `fNotSharable` field of its `WD_ITEMS` structure [B.7.6] to 1, before calling `WDC_PciDeviceOpen`().

- Maps the physical memory ranges found on the device both to kernel-mode and user-mode address space, and stores the mapped addresses in the allocated device structure for future use.

- Saves device resources information required for supporting the communication with the device. For example, the function saves the interrupt request (IRQ) number and the interrupt type, as well as retrieves and saves an interrupt handle, and this information is later used when the user calls functions to handle the device's interrupts.

- If the caller selects to use a Kernel PlugIn driver to communicate with the device, the function opens a handle to this driver and stores it for future use.

Prototype

```
DWORD DLLCALLCONV WDC_PciDeviceOpen(
    WDC_DEVICE_HANDLE *phDev,
    const WD_PCI_CARD_INFO *pDeviceInfo,
    const PVOID pDevCtx);
```

Parameters

Name	Type	Input/Output
phDev	WDC_DEVICE_HANDLE*	Output
pDeviceInfo	const WD_PCI_CARD_INFO*	Input
• pciSlot	WD_PCI_SLOT	Input
• Card	WD_CARD	Input
* dwItems	DWORD	Input
* Item	WD_ITEMS[WD_CARD_ITEMS]	Input
• item	DWORD	Input
• fNotSharable	DWORD	Input
• I	union	Input
* Mem	struct	Input
• pPhysicalAddr	PHYS_ADDR	N/A
• qwBytes	UINT64	Input
• pTransAddr	KPTR	N/A
• pUserDirectAddr	UPTR	N/A
• dwBar	DWORD	Input
• dwOptions	DWORD	Input
• pReserved	KPTR	N/A
* IO	struct	Input
• pAddr	KPTR	Input
• dwBytes	DWORD	Input
• dwBar	DWORD	Input
* Int	struct	Input
• dwInterrupt	DWORD	Input
• dwOptions	DWORD	Input
• hInterrupt	DWORD	N/A
• dwReserved1	DWORD	N/A
• pReserved2	KPTR	N/A
* Bus	struct	Input
• dwBusType	WD_BUS_TYPE	Input
• dwBusNum	DWORD	Input
• dwSlotFunc	DWORD	Input
pDevCtx	const PVOID	Input

Description

Name	Description
phDev	Pointer to a handle to the WDC device allocated by the function
pDeviceInfo	Pointer to a PCI device information structure [B.7.8], which contains information regarding the device to open
pDevCtx	Pointer to device context information, which will be stored in the device structure

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

Remarks

1. This function may be called only from the **user mode**.

2. If your card has a large memory range that cannot be fully mapped to the kernel address space, you can set the **`WD_ITEM_MEM_DO_NOT_MAP_KERNEL`** flag in the `I.Mem.dwOptions` field of the relevant `WD_ITEMS` memory resource structure [B.7.6] (`pDeviceInfo->Card.Item[i].I.Mem.dwOptions`), received from `WDC_PciGetDeviceInfo`(), before passing it to the device-open function. This flag instructs the function to map the memory range only to the user-mode virtual address space, and not to the kernel address space.

Note that if you select to set the `WD_ITEM_MEM_DO_NOT_MAP_KERNEL` flag, the device information structure that will be created by the function will not hold a kernel-mapped address for this resource (the `pAddrDesc[i].pAddr` base address kernel mapping field of the relevant memory range in the `WDC_DEVICE` structure [B.4.2] will not be updated), and you will therefore not be able to rely on this mapping in calls to WinDriver APIs — namely interrupt handling APIs or any API called from a Kernel PlugIn driver.

B.3.18. WDC_IsaDeviceOpen()

Purpose

Allocates and initializes a WDC ISA device structure, registers the device with WinDriver, and returns a handle to the device.

This function

- Verifies that none of the registered device resources (set in **`pDeviceInfo->Card.Item`**) are already locked for exclusive use.

A resource can be locked for exclusive use by setting the `fNotSharable` field of its `WD_ITEMS` structure [B.7.6] to 1, before calling `WDC_IsaDeviceOpen`().

- Maps the device's physical memory ranges device both to kernel-mode and user-mode address space, and stores the mapped addresses in the allocated device structure for future use.
- Saves device resources information required for supporting the communication with the device. For example, the function saves the interrupt request (IRQ) number and the interrupt type, as well as retrieves and saves an interrupt handle, and this information is later used when the user calls functions to handle the device's interrupts.
- If the caller selects to use a Kernel PlugIn driver to communicate with the device, the function opens a handle to this driver and stores it for future use.

Prototype

```
DWORD DLLCALLCONV WDC_IsaDeviceOpen(
    WDC_DEVICE_HANDLE *phDev,
    const WD_CARD *pDeviceInfo,
    const PVOID pDevCtx);
```

Parameters

Name	Type	Input/Output
phDev	WDC_DEVICE_HANDLE*	Output
pDeviceInfo	const WD_CARD*	Input
• dwItems	DWORD	Input
• Item	WD_ITEMS[WD_CARD_ITEMS]	Input
* item	DWORD	Input
* fNotSharable	DWORD	Input
* I	union	Input
• Mem	struct	Input
* pPhysicalAddr	PHYS_ADDR	Input
* qwBytes	UINT64	Input
* pTransAddr	KPTR	N/A
* pUserDirectAddr	UPTR	N/A
* dwBar	DWORD	Input
* dwOptions	DWORD	Input
* pReserved	KPTR	N/A
• IO	struct	Input
* pAddr	KPTR	Input

Name	Type	Input/Output
* dwBytes	DWORD	Input
* dwBar	DWORD	Input
• Int	struct	Input
* dwInterrupt	DWORD	Input
* dwOptions	DWORD	Input
* hInterrupt	DWORD	N/A
* dwReserved1	DWORD	N/A
* pReserved2	KPTR	N/A
• Bus	struct	Input
* dwBusType	WD_BUS_TYPE	Input
* dwBusNum	DWORD	Input
* dwSlotFunc	DWORD	Input
pDevCtx	const PVOID	Input

Description

Name	Description
phDev	Pointer to a handle to the WDC device allocated by the function
pDeviceInfo	Pointer to a card information structure [B.7.7], which contains information regarding the device to open
pDevCtx	Pointer to device context information, which will be stored in the device structure

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

Remarks

1. This function may be called only from the **user mode**.

2. If your card has a large memory range that cannot be fully mapped to the kernel address space, you can set the **`WD_ITEM_MEM_DO_NOT_MAP_KERNEL`** flag in the `I.Mem.dwOptions` field of the relevant `WD_ITEMS` memory resource structure [B.7.6] (`pDeviceInfo->Card.Item[i].I.Mem.dwOptions`) before passing it to the device-open function. This flag instructs the function to map the memory range only to the user-mode virtual address space, and not to the kernel address space.

Note that if you select to set the `WD_ITEM_MEM_DO_NOT_MAP_KERNEL` flag, the device information structure that will be created by the function will not hold a kernel-mapped address for this resource (the `pAddrDesc[i].pAddr` base address kernel mapping field of the relevant memory range in the `WDC_DEVICE` structure [B.4.2] will not be updated), and you will therefore not be able to rely on this mapping in calls to WinDriver APIs — namely interrupt handling APIs or any API called from a Kernel PlugIn driver.

B.3.19. WDC_PciDeviceClose()

Purpose

Uninitializes a WDC PCI device structure and frees the memory allocated for it.

Prototype

```
DWORD DLLCALLCONV WDC_PciDeviceClose(WDC_DEVICE_HANDLE hDev);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input

Description

Name	Description
hDev	Handle to a WDC PCI device structure, returned by `WDC_PciDeviceOpen`() [B.3.17]

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

Remarks

- This function can be called from the **user mode only**.

B.3.20. WDC_IsaDeviceClose()

Purpose

Uninitializes a WDC ISA device structure and frees the memory allocated for it.

Prototype

```
DWORD DLLCALLCONV WDC_IsaDeviceClose(WDC_DEVICE_HANDLE hDev);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input

Description

Name	Description
hDev	Handle to a WDC ISA device structure, returned by `WDC_IsaDeviceOpen`() [B.3.18]

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

Remarks

- This function can be called from the **user mode only**.

B.3.21. WDC_CardCleanupSetup()

Purpose

Sets a list of transfer cleanup commands to be performed for the specified card on any of the following occasions:

- The application exits abnormally.
- The application exits normally but without closing the specified card.
- If the `bForceCleanup` parameter is set to `TRUE`, the cleanup commands will also be performed when the specified card is closed.

Prototype

```
DWORD WDC_CardCleanupSetup(
    WDC_DEVICE_HANDLE hDev,
    WD_TRANSFER *Cmd,
    DWORD dwCmds,
    BOOL bForceCleanup);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
Cmd	WD_TRANSFER*	Input
dwCmds	DWORD	Input
bForceCleanup	BOOL	Input

Description

Name	Description
hDev	Handle to a WDC device, returned by `WDC_xxxDeviceOpen`() (PCI [B.3.17] / ISA [B.3.18])
Cmd	Pointer to an array of cleanup transfer commands to be performed [B.7.10]
dwCmds	Number of cleanup commands in the `Cmd` array
bForceCleanup	If **`FALSE`**: The cleanup transfer commands (`Cmd`) will be performed in either of the following cases: • When the application exits abnormally. • When the application exits normally without closing the card by calling one of the `WDC_xxxDeviceClose`() functions (PCI [B.3.19] / ISA [B.3.20]). If **`TRUE`**: The cleanup transfer commands will be performed both in the two cases described above, as well as in the following case: • When the relevant `WD_xxxDeviceClose`() function is called for the card.

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.3.22. WDC_KernelPlugInOpen()

Purpose

Opens a handle to a Kernel PlugIn driver.

Prototype

```
DWORD DLLCALLCONV WDC_KernelPlugInOpen(
    WDC_DEVICE_HANDLE hDev,
    const CHAR *pcKPDriverName,
    PVOID pKPOpenData);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input/Output
pcKPDriverName	const CHAR*	Input
pKPOpenData	PVOID	Input

Description

Name	Description
hDev	Handle to a WDC device, returned by `WDC_xxxDeviceOpen`() (PCI [B.3.17] / ISA [B.3.18])
pcKPDriverName	Kernel PlugIn driver name
pKPOpenData	Kernel PlugIn driver open data to be passed to `WD_KernelPlugInOpen`() (see the **WinDriver PCI Low-Level API Reference**)

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

Remarks

It's also possible to use the `WDC_xxxDeviceOpen`() functions (PCI [B.3.17] / ISA [B.3.18]) to open a handle to a Kernel PlugIn driver, as part of the device-open operation. However, this method cannot be used to open a handle to a 64-bit Kernel PlugIn driver from a 32-bit user-mode application. Therefore, to ensure that your code works in all the supported configurations, it is recommended that you use `WDC_KernelPlugInOpen`() to open the Kernel PlugIn driver handle. This is also the only supported method for opening a Kernel PlugIn handle from a .NET application. (See detailed information in Section 12.5.)

B.3.23. WDC_CallKerPlug()

Purpose

Sends a message from a user-mode application to a Kernel PlugIn driver. The function passes a message ID from the application to the Kernel PlugIn's `KP_Call` [B.8.4] function, which should be implemented to handle the specified message ID, and returns the result from the Kernel PlugIn to the user-mode application.

Prototype

```
DWORD DLLCALLCONV WDC_CallKerPlug(
    WDC_DEVICE_HANDLE hDev,
    DWORD dwMsg,
    PVOID pData,
    PDWORD pdwResult);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
dwMsg	DWORD	Input
pData	PVOID	Input/Output
pdwResult	pdwResult	Output

Description

Name	Description
hDev	Handle to a WDC device, returned by `WDC_xxxDeviceOpen`() (PCI [B.3.17] / ISA [B.3.18])
dwMsg	A message ID to pass to the Kernel PlugIn driver (specifically to `KP_Call` [B.8.4])
pData	Pointer to data to pass between the Kernel PlugIn driver and the user-mode application
pdwResult	Result returned by the Kernel PlugIn driver (`KP_Call`) for the operation performed in the kernel as a result of the message that was sent

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.3.24. WDC_ReadMemXXX()

Purpose

`WDC_ReadMem8/16/32/64`() reads 1 byte (8 bits) / 2 bytes (16 bits) / 4 bytes (32 bits) / 8 bytes (64 bits), respectively, from a specified memory address. The address is read directly in the calling context (user mode / kernel mode).

Prototype

```
BYTE WDC_ReadMem8(addr, off);
WORD WDC_ReadMem16(addr, off);
UINT32 WDC_ReadMem32(addr, off);
UINT64 WDC_ReadMem64(addr, off);
```

Note: The `WDC_ReadMemXXX` APIs are implemented as macros. The prototypes above use functions declaration syntax to emphasize the expected return values.

Parameters

Name	Type	Input/Output
addr	DWORD	Input
off	DWORD	Input

Description

Name	Description
addr	The memory address space to read from
off	The offset from the beginning of the specified address space (`addr`) to read from

Return Value

Returns the data that was read from the specified address.

B.3.25. WDC_WriteMemXXX()

Purpose

`WDC_WriteMem8/16/32/64`() writes 1 byte (8 bits) / 2 bytes (16 bits) / 4 bytes (32 bits) / 8 bytes (64 bits), respectively, to a specified memory address. The address is written to directly in the calling context (user mode / kernel mode).

Prototype

```
void WDC_WriteMem8(addr, off, val);
void WDC_WriteMem16(addr, off, val);
void WDC_WriteMem32(addr, off, val);
void WDC_WriteMem64(addr, off, val);
```

Note: The `WDC_WriteMemXXX` APIs are implemented as macros. The prototypes above use functions declaration syntax to emphasize the expected return values.

Parameters

Name	Type	Input/Output
addr	DWORD	Input
off	DWORD	Input
val	BYTE / WORD / UINT32 / UINT64	Input

Description

Name	Description
addr	The memory address space to read from
off	The offset from the beginning of the specified address space (`addr`) to read from
val	The data to write to the specified address

Return Value

None

B.3.26. WDC_ReadAddrXXX()

Purpose

`WDC_ReadAddr8/16/32/64`() reads 1 byte (8 bits) / 2 bytes (16 bits) / 4 bytes (32 bits) / 8 bytes (64 bits), respectively, from a specified memory or I/O address.

Prototype

```
DWORD DLLCALLCONV WDC_ReadAddr8(WDC_DEVICE_HANDLE hDev,
    DWORD dwAddrSpace, KPTR dwOffset, BYTE *val);

DWORD DLLCALLCONV WDC_ReadAddr16(WDC_DEVICE_HANDLE hDev,
    DWORD dwAddrSpace, KPTR dwOffset, WORD *val);

DWORD DLLCALLCONV WDC_ReadAddr32(WDC_DEVICE_HANDLE hDev,
    DWORD dwAddrSpace, KPTR dwOffset, UINT32 *val);

DWORD DLLCALLCONV WDC_ReadAddr64(WDC_DEVICE_HANDLE hDev,
    DWORD dwAddrSpace, KPTR dwOffset, UINT64 *val);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
dwAddrSpace	DWORD	Input
dwOffset	KPTR	Input
val	BYTE* / WORD* / UINT32* / UINT64*	Output

Description

Name	Description
hDev	Handle to a WDC device, returned by `WDC_xxxDeviceOpen`() (PCI [B.3.17] / ISA [B.3.18])
dwAddrSpace	The memory or I/O address space to read from
dwOffset	The offset from the beginning of the specified address space (`dwAddrSpace`) to read from
val	Pointer to a buffer to be filled with the data that is read from the specified address

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.3.27. WDC_WriteAddrXXX()

Purpose

`WDC_WriteAddr8/16/32/64`() writes 1 byte (8 bits) / 2 bytes (16 bits) / 4 bytes (32 bits) / 8 bytes (64 bits), respectively, to a specified memory or I/O address.

Prototype

```
DWORD DLLCALLCONV WDC_WriteAddr8(WDC_DEVICE_HANDLE hDev,
    DWORD dwAddrSpace, KPTR dwOffset, BYTE val)

DWORD DLLCALLCONV WDC_WriteAddr16(WDC_DEVICE_HANDLE hDev,
    DWORD dwAddrSpace, KPTR dwOffset, WORD val);

DWORD DLLCALLCONV WDC_WriteAddr32(WDC_DEVICE_HANDLE hDev,
    DWORD dwAddrSpace, KPTR dwOffset, UINT32 val);

DWORD DLLCALLCONV WDC_WriteAddr64(WDC_DEVICE_HANDLE hDev,
    DWORD dwAddrSpace, KPTR dwOffset, UINT64 val);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
dwAddrSpace	DWORD	Input
dwOffset	KPTR	Input
val	BYTE / WORD / UINT32 / UINT64	Input

Description

Name	Description
hDev	Handle to a WDC device, returned by `WDC_xxxDeviceOpen()` (PCI [B.3.17] / ISA [B.3.18])
dwAddrSpace	The memory or I/O address space to write to
dwOffset	The offset from the beginning of the specified address space (`dwAddrSpace`) to write to
val	The data to write to the specified address

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.3.28. WDC_ReadAddrBlock()

Purpose

Reads a block of data from the device.

Prototype

```
DWORD DLLCALLCONV WDC_ReadAddrBlock(
    WDC_DEVICE_HANDLE hDev,
    DWORD dwAddrSpace,
    KPTR dwOffset,
    DWORD dwBytes,
    PVOID pData,
    WDC_ADDR_MODE mode,
    WDC_ADDR_RW_OPTIONS options);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
dwAddrSpace	DWORD	Input
dwOffset	KPTR	Input
dwBytes	DWORD	Input
pData	PVOID	Output
mode	WDC_ADDR_MODE	Input
options	WDC_ADDR_RW_OPTIONS	Input

Description

Name	Description
hDev	Handle to a WDC device, returned by `WDC_xxxDeviceOpen()` (PCI [B.3.17] / ISA [B.3.18])
dwAddrSpace	The memory or I/O address space to read from
dwOffset	The offset from the beginning of the specified address space (`dwAddrSpace`) to read from
dwBytes	The number of bytes to read
pData	Pointer to a buffer to be filled with the data that is read from the device
mode	The read access mode — see `WDC_ADDR_MODE` [B.3.1.4]
options	A bit mask that determines how the data will be read — see `WDC_ADDR_RW_OPTIONS` [B.3.1.5]. The function automatically sets the `WDC_RW_BLOCK` flag.

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.3.29. WDC_WriteAddrBlock()

Purpose

Writes a block of data to the device.

Prototype

```
DWORD DLLCALLCONV WDC_WriteAddrBlock(
    WDC_DEVICE_HANDLE hDev,
    DWORD dwAddrSpace,
    KPTR dwOffset,
    DWORD dwBytes,
    PVOID pData,
    WDC_ADDR_MODE mode,
    WDC_ADDR_RW_OPTIONS options);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
dwAddrSpace	DWORD	Input
dwOffset	KPTR	Input
dwBytes	DWORD	Input
pData	PVOID	Input
mode	WDC_ADDR_MODE	Input
options	WDC_ADDR_RW_OPTIONS	Input

Description

Name	Description
hDev	Handle to a WDC device, returned by `WDC_xxxDeviceOpen()` (PCI [B.3.17] / ISA [B.3.18])
dwAddrSpace	The memory or I/O address space to write to
dwOffset	The offset from the beginning of the specified address space (`dwAddrSpace`) to write to
dwBytes	The number of bytes to write
pData	Pointer to a buffer that holds the data to write to the device
mode	The write access mode — see `WDC_ADDR_MODE` [B.3.1.4]
options	A bit mask that determines how the data will be written — see `WDC_ADDR_RW_OPTIONS` [B.3.1.5]. The function automatically sets the `WDC_RW_BLOCK` flag.

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.3.30. WDC_MultiTransfer()

Purpose

Performs a group of memory and/or I/O read/write transfers.

Prototype

```
DWORD DLLCALLCONV WDC_MultiTransfer(
    WD_TRANSFER *pTrans,
    DWORD dwNumTrans);
```

Parameters

Name	Type	Input/Output
pTrans	WD_TRANSFER*	
dwNumTrans	DWORD	Input

Description

Name	Description
pTrans	Pointer to an array of transfer commands information structures [B.7.10]
dwNumTrans	Number of transfer commands in the `pTrans` array

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

Remarks

- The transfers are performed using the low-level `WD_MultiTransfer`() WinDriver function, which reads/writes the specified addresses in the kernel (see the **WinDriver PCI Low-Level API Reference** for details).
- Memory addresses are read/written in the kernel (like I/O addresses) and NOT directly in the user mode, therefore the port addresses passed to this function, for both memory and I/O addresses, must be the kernel-mode mappings of the physical addresses, which are stored in the device structure [B.4.2].

B.3.31. WDC_AddrSpaceIsActive()

Purpose

Checks if the specified memory or I/O address space is active — i.e., if its size is not zero.

Prototype

```
BOOL DLLCALLCONV WDC_AddrSpaceIsActive(
    WDC_DEVICE_HANDLE hDev,
    DWORD dwAddrSpace);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
dwAddrSpace	DWORD	Input

Description

Name	Description
hDev	Handle to a WDC device, returned by `WDC_xxxDeviceOpen()` (PCI [B.3.17] / ISA [B.3.18])
dwAddrSpace	The memory or I/O address space to look for

Return Value

Returns `TRUE` if the specified address space is active; otherwise returns `FALSE`.

B.3.32. WDC_PciReadCfgBySlot()

Purpose

Reads data from a specified offset in a PCI device's configuration space or a PCI Express device's extended configuration space.
The device is identified by its location on the PCI bus.

Access to the PCI Express extended configuration space is supported on target platforms that support such access (e.g., Windows and Linux). For such platforms, all *PCI* references in the following documentation include PCI Express as well.

Prototype

```
DWORD DLLCALLCONV WDC_PciReadCfgBySlot(
    WD_PCI_SLOT *pPciSlot,
    DWORD dwOffset,
    PVOID pData,
    DWORD dwBytes);
```

Parameters

Name	Type	Input/Output
pPciSlot	WD_PCI_SLOT*	Input
dwOffset	DWORD	Input
pData	PVOID	Output
dwBytes	DWORD	Input

Description

Name	Description
pPciSlot	Pointer to a PCI device location information structure [B.7.4], which can be acquired by calling `WDC_PciScanDevices`() [B.3.4]
dwOffset	The offset from the beginning of the PCI configuration space to read from
pData	Pointer to a buffer to be filled with the data that is read from the PCI configuration space
dwBytes	The number of bytes to read

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.3.33. WDC_PciWriteCfgBySlot()

Purpose

Write data to a specified offset in a PCI device's configuration space or a PCI Express device's extended configuration space.
The device is identified by its location on the PCI bus.

Access to the PCI Express extended configuration space is supported on target platforms that support such access (e.g., Windows and Linux). For such platforms, all *PCI* references in the following documentation include PCI Express as well.

Prototype

```
DWORD DLLCALLCONV WDC_PciWriteCfgBySlot(
    WD_PCI_SLOT *pPciSlot,
    DWORD dwOffset,
    PVOID pData,
    DWORD dwBytes);
```

Parameters

Name	Type	Input/Output
pPciSlot	WD_PCI_SLOT*	Input
dwOffset	DWORD	Input
pData	PVOID	Input
dwBytes	DWORD	Input

Description

Name	Description
pPciSlot	Pointer to a PCI device location information structure [B.7.4], which can be acquired by calling `WDC_PciScanDevices`() [B.3.4]
dwOffset	The offset from the beginning of the PCI configuration space to write to
pData	Pointer to a data buffer that holds the data to write
dwBytes	The number of bytes to write

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.3.34. WDC_PciReadCfg()

Purpose

Reads data from a specified offset in a PCI device's configuration space or a PCI Express device's extended configuration space.

Access to the PCI Express extended configuration space is supported on target platforms that support such access (e.g., Windows and Linux). For such platforms, all *PCI* references in the following documentation include PCI Express as well.

Prototype

```
DWORD DLLCALLCONV WDC_PciReadCfg(
    WDC_DEVICE_HANDLE hDev,
    DWORD dwOffset,
    PVOID pData,
    DWORD dwBytes);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
dwOffset	DWORD	Input
pData	PVOID	Output
dwBytes	DWORD	Input

Description

Name	Description
hDev	Handle to a WDC PCI device structure, returned by `WDC_PciDeviceOpen()` [B.3.17]
dwOffset	The offset from the beginning of the PCI configuration space to read from
pData	Pointer to a buffer to be filled with the data that is read from the PCI configuration space
dwBytes	The number of bytes to read

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.3.35. WDC_PciWriteCfg()

Purpose

Writes data to a specified offset in a PCI device's configuration space or a PCI Express device's extended configuration space.

Access to the PCI Express extended configuration space is supported on target platforms that support such access (e.g., Windows and Linux). For such platforms, all *PCI* references in the following documentation include PCI Express as well.

Prototype

```
DWORD DLLCALLCONV WDC_PciWriteCfg(
    WDC_DEVICE_HANDLE hDev,
    DWORD dwOffset,
    PVOID pData,
    DWORD dwBytes);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
dwOffset	DWORD	Input
pData	PVOID	Input
dwBytes	DWORD	Input

Description

Name	Description
hDev	Handle to a WDC PCI device structure, returned by `WDC_PciDeviceOpen`() [B.3.17]
dwOffset	The offset from the beginning of the PCI configuration space to write to
pData	Pointer to a data buffer that holds the data to write
dwBytes	The number of bytes to write

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.3.36. WDC_PciReadCfgBySlotXXX()

Purpose

`WDC_PciReadCfgBySlot8/16/32/64`() reads 1 byte (8 bits) / 2 bytes (16 bits) / 4 bytes (32 bits) / 8 bytes (64 bits), respectively, from a specified offset in a PCI device's configuration space or a PCI Express device's extended configuration space.
The device is identified by its location on the PCI bus.

Access to the PCI Express extended configuration space is supported on target platforms that support such access (e.g., Windows and Linux). For such platforms, all *PCI* references in the following documentation include PCI Express as well.

Prototype

```
DWORD DLLCALLCONV WDC_PciReadCfgRegBySlot8(
    WD_PCI_SLOT *pPciSlot, DWORD dwOffset, BYTE *val);

DWORD DLLCALLCONV WDC_PciReadCfgReg1BySlot6(
    WD_PCI_SLOT *pPciSlot, DWORD dwOffset, WORD *val);

DWORD DLLCALLCONV WDC_PciReadCfgReg32BySlot(
    WD_PCI_SLOT *pPciSlot, DWORD dwOffset, UINT32 *val);

DWORD DLLCALLCONV WDC_PciReadCfgReg64BySlot(
    WD_PCI_SLOT *pPciSlot, DWORD dwOffset, UINT64 *val);
```

Parameters

Name	Type	Input/Output
pPciSlot	WD_PCI_SLOT*	Input
dwOffset	DWORD	Input
val	BYTE* / WORD* / UINT32* / UINT64*	Output

Description

Name	Description
pPciSlot	Pointer to a PCI device location information structure [B.7.4], which can be acquired by calling `WDC_PciScanDevices`() [B.3.4]
dwOffset	The offset from the beginning of the PCI configuration space to read from
val	Pointer to a buffer to be filled with the data that is read from the PCI configuration space

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.3.37. WDC_PciWriteCfgBySlotXXX()

Purpose

`WDC_PciWriteCfgBySlot8/16/32/64`() writes 1 byte (8 bits) / 2 bytes (16 bits) / 4 bytes (32 bits) / 8 bytes (64 bits), respectively, to a specified offset in a PCI device's configuration space or a PCI Express device's extended configuration space.
The device is identified by its location on the PCI bus.

Access to the PCI Express extended configuration space is supported on target platforms that support such access (e.g., Windows and Linux). For such platforms, all *PCI* references in the following documentation include PCI Express as well.

Prototype

```
DWORD DLLCALLCONV WDC_PciWriteCfgRegBySlot8(
    WD_PCI_SLOT *pPciSlot, DWORD dwOffset, BYTE val);

DWORD DLLCALLCONV WDC_PciWriteCfgRegBySlot16(
    WD_PCI_SLOT *pPciSlot, DWORD dwOffset, WORD val);

DWORD DLLCALLCONV WDC_PciWriteCfgRegBySlot32(
    WD_PCI_SLOT *pPciSlot, DWORD dwOffset, UINT32 val);

DWORD DLLCALLCONV WDC_PciWriteCfgRegBySlot64(
    WD_PCI_SLOT *pPciSlot, DWORD dwOffset, UINT64 val);
```

Parameters

Name	Type	Input/Output
pPciSlot	WD_PCI_SLOT*	Input
dwOffset	DWORD	Input
val	BYTE / WORD / UINT32 / UINT64	Input

Description

Name	Description
pPciSlot	Pointer to a PCI device location information structure [B.7.4], which can be acquired by calling `WDC_PciScanDevices`() [B.3.4]
dwOffset	The offset from the beginning of the PCI configuration space to read from
val	The data to write to the PCI configuration space

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.3.38. WDC_PciReadCfgXXX()

Purpose

`WDC_PciReadCfg8/16/32/64`() reads 1 byte (8 bits) / 2 bytes (16 bits) / 4 bytes (32 bits) / 8 bytes (64 bits), respectively, from a specified offset in a PCI device's configuration space or a PCI Express device's extended configuration space.

Access to the PCI Express extended configuration space is supported on target platforms that support such access (e.g., Windows and Linux). For such platforms, all *PCI* references in the following documentation include PCI Express as well.

Prototype

```
DWORD DLLCALLCONV WDC_PciReadCfgReg8(WDC_DEVICE_HANDLE hDev,
    DWORD dwOffset, BYTE *val);

DWORD DLLCALLCONV WDC_PciReadCfgReg16(WDC_DEVICE_HANDLE hDev,
    DWORD dwOffset, WORD *val);

DWORD DLLCALLCONV WDC_PciReadCfgReg32(WDC_DEVICE_HANDLE hDev,
    DWORD dwOffset, UINT32 *val);

DWORD DLLCALLCONV WDC_PciReadCfgReg64(WDC_DEVICE_HANDLE hDev,
    DWORD dwOffset, UINT64 *val);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
dwOffset	DWORD	Input
val	BYTE* / WORD* / UINT32* / UINT64*	Output

Description

Name	Description
hDev	Handle to a WDC PCI device structure, returned by `WDC_PciDeviceOpen`() [B.3.17]
dwOffset	The offset from the beginning of the PCI configuration space to read from
val	Pointer to a buffer to be filled with the data that is read from the PCI configuration space

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.3.39. WDC_PciWriteCfgXXX()

Purpose

`WDC_PciWriteCfg8/16/32/64`() writes 1 byte (8 bits) / 2 bytes (16 bits) / 4 bytes (32 bits) / 8 bytes (64 bits), respectively, to a specified offset in a PCI device's configuration space or a PCI Express device's extended configuration space.

Access to the PCI Express extended configuration space is supported on target platforms that support such access (e.g., Windows and Linux). For such platforms, all *PCI* references in the following documentation include PCI Express as well.

Prototype

```
DWORD DLLCALLCONV WDC_PciWriteCfgReg8(WDC_DEVICE_HANDLE hDev,
    DWORD dwOffset, BYTE val);

DWORD DLLCALLCONV WDC_PciWriteCfgReg16(WDC_DEVICE_HANDLE hDev,
    DWORD dwOffset, WORD val);

DWORD DLLCALLCONV WDC_PciWriteCfgReg32(WDC_DEVICE_HANDLE hDev,
    DWORD dwOffset, UINT32 val);

DWORD DLLCALLCONV WDC_PciWriteCfgReg64(WDC_DEVICE_HANDLE hDev,
    DWORD dwOffset, UINT64 val);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
dwOffset	DWORD	Input
val	BYTE / WORD / UINT32 / UINT64	Input

Description

Name	Description
hDev	Handle to a WDC PCI device structure, returned by `WDC_PciDeviceOpen`() [B.3.17]
dwOffset	The offset from the beginning of the PCI configuration space to read from
val	The data to write to the PCI configuration space

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.3.40. WDC_DMAContigBufLock()

Purpose

Allocates a contiguous DMA buffer, locks it in physical memory, and returns mappings of the allocated buffer to physical address space and to user-mode and kernel virtual address spaces.

Prototype

```
DWORD DLLCALLCONV WDC_DMAContigBufLock(
    WDC_DEVICE_HANDLE hDev,
    PVOID *ppBuf,
    DWORD dwOptions,
    DWORD dwDMABufSize,
    WD_DMA **ppDma);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
ppBuf	PVOID*	Output
dwOptions	DWORD	Input
dwDMABufSize	DWORD	Input
ppDma	WD_DMA**	Output

Description

Name	Description
hDev	Handle to a WDC device, returned by `WDC_xxxDeviceOpen()` (PCI [B.3.17] / ISA [B.3.18]).
ppBuf	Pointer to a pointer to be filled by the function with the user-mode mapped address of the allocated DMA buffer
dwOptions	A bit mask of any of the following flags (defined in an enumeration in **windrvr.h**): • **`DMA_FROM_DEVICE`**: Synchronize the DMA buffer for transfers from the device to memory. • **`DMA_TO_DEVICE`**: Synchronize the DMA buffer for transfers from memory to the device. • **`DMA_TO_FROM_DEVICE`**: Synchronize the DMA buffer for transfers in both directions — i.e., from the device to memory and from memory to the device (<=> `DMA_FROM_DEVICE | DMA_TO_DEVICE`). • **`DMA_ALLOW_CACHE`**: Allow caching of the memory. • **`DMA_KBUF_BELOW_16M`**: Allocate the physical DMA buffer within the lower 16MB of the main memory. • **`DMA_ALLOW_64BIT_ADDRESS`**: Allow allocation of 64-bit DMA addresses. This flag is supported on Windows and Linux.
dwDMABufSize	The size (in bytes) of the DMA buffer
ppDma	Pointer to a pointer to a DMA buffer information structure [B.7.9], which is allocated by the function. The pointer to this structure (`*ppDma`) should be passed to `WDC_DMABufUnlock()` [B.3.43] when the DMA buffer is no longer needed.

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

Remarks

- When calling this function you do **not** need to set the `DMA_KERNEL_BUFFER_ALLOC` flag, since the function sets this flag automatically.
- This function is currently only supported from the user mode.
- On Windows x86 and x86_64 platforms, you should normally set the `DMA_ALLOW_CACHE` flag in the DMA options bitmask parameter (`dwOptions`).

- If the device supports 64-bit DMA addresses, it is recommended to set the `DMA_ALLOW_64BIT_ADDRESS` flag in `dwOptions`. Otherwise, when the physical memory on the target platform is larger than 4GB, the operating system may only allow allocation of relatively small 32-bit DMA buffers (such as 1MB buffers, or even smaller).

B.3.41. WDC_DMASGBufLock()

Purpose

Locks a pre-allocated user-mode memory buffer for DMA and returns the corresponding physical mappings of the locked DMA pages. On Windows the function also returns a kernel-mode mapping of the buffer.

Prototype

```
DWORD DLLCALLCONV WDC_DMASGBufLock(
    WDC_DEVICE_HANDLE hDev,
    PVOID pBuf,
    DWORD dwOptions,
    DWORD dwDMABufSize,
    WD_DMA **ppDma);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
pBuf	PVOID	Input
dwOptions	DWORD	Input
dwDMABufSize	DWORD	Input
ppDma	WD_DMA**	Output

Description

Name	Description
hDev	Handle to a WDC device, returned by `WDC_xxxDeviceOpen()` (PCI [B.3.17] / ISA [B.3.18])
pBuf	Pointer to a user-mode buffer to be mapped to the allocated physical DMA buffer(s)
dwOptions	A bit mask of any of the following flags (defined in an enumeration in **windrvr.h**): • **`DMA_FROM_DEVICE`**: Synchronize the DMA buffer for transfers from the device to memory. • **`DMA_TO_DEVICE`**: Synchronize the DMA buffer for transfers from memory to the device. • **`DMA_TO_FROM_DEVICE`**: Synchronize the DMA buffer for transfers in both directions — i.e., from the device to memory and from memory to the device (<=> `DMA_FROM_DEVICE | DMA_TO_DEVICE`). • **`DMA_ALLOW_CACHE`**: Allow caching of the memory. • **`DMA_ALLOW_64BIT_ADDRESS`**: Allow allocation of 64-bit DMA addresses. This flag is supported on Windows and Linux.
dwDMABufSize	The size (in bytes) of the DMA buffer
ppDma	Pointer to a pointer to a DMA buffer information structure [B.7.9], which is allocated by the function. The pointer to this structure (`*ppDma`) should be passed to `WDC_DMABufUnlock()` [B.3.43] when the DMA buffer is no longer needed.

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

Remarks

- When calling the function to allocate large buffers (> 1MB) you do **not** need to set the `DMA_LARGE_BUFFER` flag, which is used for allocation of large Scatter/Gather DMA buffers using the low-level WinDriver `WD_DMALock()` function (see the **WinDriver PCI Low-Level API Reference**), since `WDC_DMASGBufLock()` handles this for you.

- This function is currently only supported from the user mode.

- On Windows x86 and x86_64 platforms, you should normally set the `DMA_ALLOW_CACHE` flag in the DMA options bitmask parameter (`dwOptions`).

- If the device supports 64-bit DMA addresses, it is recommended to set the `DMA_ALLOW_64BIT_ADDRESS` flag in `dwOptions`. Otherwise, when the physical memory on the target platform is larger than 4GB, the operating system may only allow allocation of relatively small 32-bit DMA buffers (such as 1MB buffers, or even smaller).

B.3.42. WDC_DMAReservedBufLock()

Purpose

Locks a physical reserved memory buffer for DMA and returns the corresponding user mode address of locked DMA buffer.

The physical address returned from this API (ppDma->Page[0].pPhysicalAddr) may be different then the address supplied by the caller (qwAddr) when the system uses IOMMU. When performing DMA transfer using this mapped buffer, make sure to use the returned address.

Prototype

```
DWORD DLLCALLCONV WDC_DMAReservedBufLock(
    WDC_DEVICE_HANDLE hDev,
    PHYS_ADDR qwAddr,
    PVOID *ppBuf,
    DWORD dwOptions,
    DWORD dwDMABufSize,
    WD_DMA **ppDma);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
qwAddr	PHYS_ADDR	Input
ppBuf	PVOID *	Output
dwOptions	DWORD	Input
dwDMABufSize	DWORD	Input
ppDma	WD_DMA**	Output

Description

Name	Description
hDev	Handle to a WDC device, returned by `WDC_xxxDeviceOpen()` (PCI [B.3.17] / ISA [B.3.18])
qwAddr	Physical address of the reserved buffer to lock
ppBuf	Pointer to a pointer to be filled by the function with the user-mode mapped address of the locked DMA buffer
dwOptions	A bit mask of any of the following flags (defined in an enumeration in **windrvr.h**): • **`DMA_FROM_DEVICE`**: Synchronize the DMA buffer for transfers from the device to memory. • **`DMA_TO_DEVICE`**: Synchronize the DMA buffer for transfers from memory to the device. • **`DMA_TO_FROM_DEVICE`**: Synchronize the DMA buffer for transfers in both directions — i.e., from the device to memory and from memory to the device (<=> `DMA_FROM_DEVICE | DMA_TO_DEVICE`). • **`DMA_ALLOW_64BIT_ADDRESS`**: Allow allocation of 64-bit DMA addresses. This flag is supported on Windows and Linux.
dwDMABufSize	The size (in bytes) of the DMA buffer
ppDma	Pointer to a pointer to a DMA buffer information structure [B.7.9], which is allocated by the function. The pointer to this structure (`*ppDma`) should be passed to `WDC_DMABufUnlock()` [B.3.43] when the DMA buffer is no longer needed.

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.3.43. WDC_DMABufUnlock()

Purpose

Unlocks and frees the memory allocated for a DMA buffer by a previous call to `WDC_DMAContigBufLock`() [B.3.40], `WDC_DMASGBufLock`() [B.3.41] or `WDC_DMAReservedBufLock`() [B.3.42].

Prototype

```
DWORD DLLCALLCONV WDC_DMABufUnlock(WD_DMA *pDma);
```

Parameters

Name	Type	Input/Output
pDma	WD_DMA*	Input

Description

Name	Description
pDma	Pointer to a DMA information structure [B.7.9], received from a previous call to `WDC_DMAContigBufLock`() [B.3.40] (for a contiguous DMA buffer) or `WDC_DMASGBufLock`() [B.3.41] (for a Scatter/Gather DMA buffer) — `*ppDma` returned by these functions

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

Remarks

- This function is currently only supported from the user mode.

B.3.44. WDC_DMABufGet()

Purpose

Retrieves a contiguous DMA buffer which was allocated by another process.

This API is not part of the standard WinDriver APIs, and is not included in the standard version of WinDriver. It is part of "WinDriver for Server" API and requires "WinDriver for Server" license. Note that "WinDriver for Server" APIs are included in WinDriver evaluation version.

Prototype

```
DWORD DLLCALLCONV WDC_DMABufGet(DWORD hDma, WD_DMA **ppDma);
```

Before calling this API, the calling process should recieve the global buffer handle via WinDriver IPC mechanism from the process that allocated the buffer.

Once the process finish using the shared buffer, it should release it using the regular unlock method- `WDC_DMABufUnlock()` [B.3.43].

Parameters

Name	Type	Input/Output
hDma	DWORD	Input
ppDma	WD_DMA**	Output

Description

Name	Description
hDma	DMA buffer handle.
ppDma	Pointer to a pointer to a DMA buffer information structure [B.7.9], which is associated with hDma.

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.3.45. WDC_DMAGetGlobalHandle Macro

Purpose

Utility macro that returns a contiguous DMA global handle that can be used for buffer sharing between multiple processes.

Prototype

```
WDC_DMAGetGlobalHandle(pDma)
```

Parameters

Name	Type	Input/Output
pDma	WD_DMA*	Input

Description

Name	Description
pDma	Pointer to a DMA information structure [B.7.9], received from a previous call to `WDC_DMAContigBufLock()` [B.3.40]

Return Value

DMA buffer handle of pDma.

B.3.46. WDC_DMASyncCpu()

Purpose

Synchronizes the cache of all CPUs with the DMA buffer, by flushing the data from the CPU caches.

This function should be called before performing a DMA transfer (see Remarks below).

Prototype

```
DWORD DLLCALLCONV WDC_DMASyncCpu(WD_DMA *pDma);
```

Parameters

Name	Type	Input/Output
pDma	WD_DMA*	Input

Description

Name	Description
pDma	Pointer to a DMA information structure [B.7.9], received from a previous call to `WDC_DMAContigBufLock`() [B.3.40] (for a contiguous DMA buffer) or `WDC_DMASGBufLock`() [B.3.41] (for a Scatter/Gather DMA buffer) — `*ppDma` returned by these functions

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

Remarks

- An asynchronous DMA read or write operation accesses data in memory, not in the processor (CPU) cache, which resides between the CPU and the host's physical memory. Unless the CPU cache has been flushed, by calling `WDC_DMASyncCpu`(), just before a read transfer, the data transferred into system memory by the DMA operation could be overwritten with stale data if the CPU cache is flushed later. Unless the CPU cache has been flushed by calling `WDC_DMASyncCpu`() just before a write transfer, the data in the CPU cache might be more up-to-date than the copy in memory.

- This function is currently only supported from the user mode.

B.3.47. WDC_DMASyncIo()

Purpose

Synchronizes the I/O caches with the DMA buffer, by flushing the data from the I/O caches and updating the CPU caches.

This function should be called after performing a DMA transfer (see Remarks below).

Prototype

```
DWORD DLLCALLCONV WDC_DMASyncIo(WD_DMA *pDma);
```

Parameters

Name	Type	Input/Output
pDma	WD_DMA*	Input

Description

Name	Description
pDma	Pointer to a DMA information structure, received from a previous call to `WDC_DMAContigBufLock()` [B.3.40] (for a contiguous DMA buffer) or `WDC_DMASGBufLock()` [B.3.41] (for a Scatter/Gather DMA buffer) — `*ppDma` returned by these functions

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

Remarks

- After a DMA transfer has been completed, the data can still be in the I/O cache, which resides between the host's physical memory and the bus-master DMA device, but not yet in the host's main memory. If the CPU accesses the memory, it might read the wrong data from the CPU cache. To ensure a consistent view of the memory for the CPU, you should call `WDC_DMASyncIo()` after a DMA transfer in order to flush the data from the I/O cache and update the CPU cache with the new data. The function also flushes additional caches and buffers between the device and memory, such as caches associated with bus extenders or bridges.

- This function is currently only supported from the user mode.

B.3.48. WDC_IntEnable()

Purpose

Enables interrupt handling for the device.

On Linux and Windows 7 and higher, when attempting to enable interrupts for a PCI device that supports Extended Message-Signaled Interrupts (MSI-X) or Message-Signaled Interrupts (MSI) (and was installed with a relevant INF file — on **Windows** [9.2.7.1]), the function first tries to enable MSI-X or MSI; if this fails, or if the target OS does not support MSI/MSI-X, the function attempts to enable legacy level-sensitive interrupts (if supported by the device).
On **Linux**, you can use the function's **dwOptions** parameter to specify the types of PCI interrupts that may be enabled for the device (see the explanation in the parameter description).
For other types of hardware (PCI with no MSI/MSI-X support / ISA), the function attempts to enable the legacy interrupt type supported by the device (Level Sensitive / Edge Triggered) — see further information in Section 9.2.

When enabling interrupts using a **Kernel PlugIn** driver (`fUseKP=TRUE`), the Kernel PlugIn functions used to handle the interrupts are derived from the type of interrupts enabled for the device: for MSI/MSI-X, the `KP_IntAtIrqlMSI` and `KP_IntAtDpcMSI` functions are used; otherwise, the `KP_IntAtIrql` and `KP_IntAtDpc` functions are used.

If the caller selects to handle the interrupts in the kernel, using a **Kernel PlugIn** driver, the Kernel PlugIn `KP_IntAtIrql` [B.8.8] (legacy interrupts) or `KP_IntAtIrqlMSI` [B.8.10] (MSI/MSI-X) function, which runs at high interrupt request level (IRQL), will be invoked immediately when an interrupt is received.

The function can receive transfer commands information, which will be performed by WinDriver at the kernel, at high IRQ level, when an interrupt is received (see further information in Section 9.2.6). If a **Kernel PlugIn** driver is used to handle the interrupts, any transfer commands set by the caller will be executed by WinDriver after the Kernel PlugIn `KP_IntAtDpc` or `KP_IntAtDpcMSI` function completes its execution.
When handling level-sensitive interrupts (such as legacy PCI interrupts) from the **user mode**, without a Kernel PlugIn driver, you must prepare and pass to the function transfer commands for acknowledging the interrupt. When using a **Kernel PlugIn** driver, the information for acknowledging the interrupts should be implemented in the Kernel PlugIn `KP_IntAtIrql` function [B.8.8], so the transfer commands in the call to `WDC_IntEnable`() are not required (although they can still be used).

The function receives a user-mode interrupt handler routine, which will be called by WinDriver after the kernel-mode interrupt processing is completed.
If the interrupts are handled using a **Kernel PlugIn** driver, the return value of the Kernel PlugIn deferred interrupt handler function — `KP_IntAtDpc` [B.8.9] (legacy interrupts) or `KP_IntAtDpcMSI` [B.8.11] (MSI/MSI-X) — will determine how many times (if at all) the user-mode interrupt handler will be called (provided `KP_IntAtDpc` or `KP_IntAtDpcMSI` itself is executed — which is determined by the return value of the Kernel PlugIn `KP_IntAtIrql` [B.8.8] or `KP_IntAtIrqlMSI` [B.8.10] function).

Prototype

```
DWORD DLLCALLCONV WDC_IntEnable(
    WDC_DEVICE_HANDLE hDev,
    WD_TRANSFER *pTransCmds,
    DWORD dwNumCmds,
    DWORD dwOptions,
    INT_HANDLER funcIntHandler,
    PVOID pData,
    BOOL fUseKP);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
pTransCmds	WD_TRANSFER*	Input
dwNumCmds	DWORD	Input
dwOptions	DWORD	Input
funcIntHandler	typedef void (*INT_HANDLER)(PVOID pData);	Input
pData	PVOID	Input
fUseKP	BOOL	Input

Description

Name	Description
hDev	Handle to a WDC device, returned by `WDC_xxxDeviceOpen`() (PCI [B.3.17] / ISA [B.3.18])
pTransCmds	An array of transfer commands information structures that define the operations to be performed at the kernel level upon the detection of an interrupt, or `NULL` if no transfer commands are required. NOTE: • Memory allocated for the transfer commands must remain available until the interrupts are disabled . • When handling level-sensitive interrupts (such as legacy PCI interrupts) without a Kernel PlugIn [11], you must use this array to define the hardware-specific commands for acknowledging the interrupts in the kernel, immediately when they are received — see further information in Section 9.2. For an explanation on how to set the transfer commands, refer to the description of `WD_TRANSFER` in Section B.7.10, and to the explanation in Section 9.2.6.
dwNumCmds	Number of transfer commands in the `pTransCmds` array

Name	Description
dwOptions	A bit mask of interrupt handling flags — can be set to zero for no options, or to a combination of any of the following flags: • **`INTERRUPT_CMD_COPY`**: If set, WinDriver will copy any data read in the kernel as a result of a read transfer command, and return it to the user within the relevant transfer command structure. The user will be able to access the data from his user-mode interrupt handler routine (**`funcIntHandler`**). The following flags are applicable only to PCI interrupts on **Linux**. If set, these flags determine the types of interrupts that may be enabled for the device — the function will attempt to enable only interrupts of the specified types, using the following precedence order, provided the type is reported as supported by the device: • **`INTERRUPT_MESSAGE_X`**: Extended Message-Signaled Interrupts (MSI-X) • **`INTERRUPT_MESSAGE`**: Message-Signaled Interrupts (MSI) • **`INTERRUPT_LEVEL_SENSITIVE`** — Legacy level-sensitive interrupts
funcIntHandler	A user-mode interrupt handler callback function, which will be executed after an interrupt is received and processed in the kernel. (The prototype of the interrupt handler — `INT_HANDLER` — is defined in **windrvr_int_thread.h**).
pData	Data for the user-mode interrupt handler callback routine (**`funcIntHandler`**)
fUseKP	If **`TRUE`** — The device's Kernel PlugIn driver's `KP_IntAtIrql` [B.8.8] or `KP_IntAtIrqlMSI` [B.8.10] function, which runs at high interrupt request level (IRQL), will be executed immediately when an interrupt is received. The Kernel PlugIn driver to be used for the device is passed to `WDC_xxxDeviceOpen`() and stored in the WDC device structure. If the caller also passes transfer commands to the function (**`pTransCmds`**), these commands will be executed by WinDriver at the kernel, at high IRQ level, after `KP_IntAtIrql` or `KP_IntAtIrqlMSI` completes its execution. If the high-IRQL handler returns `TRUE`, the Kernel PlugIn deferred interrupt processing routine — `KP_IntAtDpc` [B.8.9] or `KP_IntAtDpcMSI` [B.8.11] — will be invoked. The return value of this function determines how many times (if at all) the user-mode interrupt handler (**`funcIntHandler`**) will be executed once the control returns to the user mode. If **`FALSE`** — When an interrupt is received, any transfer commands set by the user in **`pTransCmds`** will be executed by WinDriver at the kernel, at high IRQ level, and the user-mode interrupt handler routine (**`funcIntHandler`**) will be executed when the control returns to the user mode.

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

Remarks

- This function can be called from the **user mode only**.
- The function enables interrupt handling in the software. After it returns successfully you must physically enable generation of interrupts in the hardware (you should be able to do so by writing to the device from the code).
- A successful call to this function must be followed with a call to `WDC_IntDisable`() later on in the code, in order to disable the interrupts.
  The `WDC_xxxDriverClose`() functions (PCI: [B.3.19], ISA: [B.3.20]) call `WDC_IntDisable`() if the device's interrupts are enabled.
- WinDriver must be registered with the OS as the driver of the device before enabling interrupts. For Plug-and-Play hardware (PCI/PCI Express) on Windows platforms, this association is made by installing an INF file for the device [15.1]. If the INF file is not installed, `WDC_IntEnable`() will fail with a `WD_NO_DEVICE_OBJECT` error [B.11].

B.3.49. WDC_IntDisable()

Purpose

Disables interrupt interrupt handling for the device, pursuant to a previous call to `WDC_IntEnable()` [B.3.48].

Prototype

```
DWORD DLLCALLCONV WDC_IntDisable(WDC_DEVICE_HANDLE hDev);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input

Description

Name	Description
hDev	Handle to a WDC device, returned by `WDC_xxxDeviceOpen()` (PCI [B.3.17] / ISA [B.3.18])

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

Remarks

- This function can be called from the **user mode only**.

B.3.50. WDC_IntIsEnabled()

Purpose

Checks if a device's interrupts are currently enabled.

Prototype

```
BOOL DLLCALLCONV WDC_IntIsEnabled(WDC_DEVICE_HANDLE hDev);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input

Description

Name	Description
hDev	Handle to a WDC device, returned by `WDC_xxxDeviceOpen`() (PCI [B.3.17] / ISA [B.3.18])

Return Value

Returns `TRUE` if the device's interrupts are enabled; otherwise returns `FALSE`.

B.3.51. WDC_IntType2Str()

Purpose

Converts interrupt type to string.

Prototype

```
const CHAR * DLLCALLCONV WDC_IntType2Str(DWORD dwIntType);
```

Parameters

Name	Type	Input/Output
dwIntType	DWORD	Input

Description

Name	Description
dwIntType	Interrupt types bit-mask

Return Value

Returns the string representation that corresponds to the specified numeric code.

B.3.52. WDC_EventRegister()

Purpose

Registers the application to receive Plug-and-Play and power management events notifications for the device.

Prototype

```
DWORD DLLCALLCONV WDC_EventRegister(
    WDC_DEVICE_HANDLE hDev,
    DWORD dwActions,
    EVENT_HANDLER funcEventHandler,
    PVOID pData,
    BOOL fUseKP);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
dwActions	DWORD	Input
funcEventHandler	typedef void (*EVENT_HANDLER)(WD_EVENT *pEvent, void *pData);	Input
pData	PVOID	Input
fUseKP	BOOL	Input

Description

Name	Description
hDev	Handle to a Plug-and-Play WDC device, returned by `WDC_PciDeviceOpen`() [B.3.17]
dwActions	A bit mask of flags indicating which events to register to: **Plug-and-Play events:** • **`WD_INSERT`** — Device inserted • **`WD_REMOVE`** — Device removed **Device power state change events:** • **`WD_POWER_CHANGED_D0`** — Full power • **`WD_POWER_CHANGED_D1`** — Low sleep • **`WD_POWER_CHANGED_D2`** — Medium sleep • **`WD_POWER_CHANGED_D3`** — Full sleep • **`WD_POWER_SYSTEM_WORKING`** — Fully on **Systems power state:** • **`WD_POWER_SYSTEM_SLEEPING1`** — Fully on but sleeping • **`WD_POWER_SYSTEM_SLEEPING2`** — CPU off, memory on, PCI on • **`WD_POWER_SYSTEM_SLEEPING3`** — CPU off, Memory is in refresh, PCI on aux power • **`WD_POWER_SYSTEM_HIBERNATE`** — OS saves context before shutdown • **`WD_POWER_SYSTEM_SHUTDOWN`** — No context saved
funcEventHandler	A user-mode event handler callback function, which will be called when an event for which the caller registered to receive notifications (see **`dwActions`**) occurs. (The prototype of the event handler — `EVENT_HANDLER` — is defined in **windrvr_events.h**.)
pData	Data for the user-mode event handler callback routine (**`funcEventHandler`**)
fUseKP	If **`TRUE`** — When an event for which the caller registered to receive notifications (**`dwActions`**) occurs, the device's Kernel PlugIn driver's `KP_Event` function [B.8.5] will be called. (The Kernel PlugIn driver to be used for the device is passed to `WDC_xxxDeviceOpen`() and stored in the WDC device structure). If this function returns `TRUE`, the user-mode events handler callback function (**`funcEventHandler`**) will be called when the kernel-mode event processing is completed. If **`FALSE`** — When an event for which the caller registered to receive notifications (**`dwActions`**) occurs, the user-mode events handler callback function will be called.

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

Remarks

- This function can be called from the **user mode only**.
- A successful call to this function must be followed with a call to `WDC_EventUnregister`() [B.3.53] later on in the code, in order to unregister from receiving Plug-and-play and power management notifications from the device.

B.3.53. WDC_EventUnregister()

Purpose

Unregisters an application from a receiving Plug-and-Play and power management notifications for a device, pursuant to a previous call to `WDC_EventRegister`() [B.3.52].

Prototype

```
DWORD DLLCALLCONV WDC_EventUnregister(WDC_DEVICE_HANDLE hDev);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input

Description

Name	Description
hDev	Handle to a Plug-and-Play WDC device, returned by `WDC_PciDeviceOpen`() [B.3.17]

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

Remarks

- This function can be called from the **user mode only**.

B.3.54. WDC_EventIsRegistered()

Purpose

Checks if the application is currently registered to receive Plug-and-Play and power management notifications for the device.

Prototype

```
BOOL DLLCALLCONV WDC_EventIsRegistered(WDC_DEVICE_HANDLE hDev);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input

Description

Name	Description
hDev	Handle to a Plug-and-Play WDC device, returned by WDC_PciDeviceOpen() [B.3.17]

Return Value

Returns TRUE if the application is currently registered to receive Plug-and-Play and power management notifications for the device; otherwise returns FALSE.

B.3.55. WDC_SetDebugOptions()

Purpose

Sets debug options for the WDC library — see the description of WDC_DBG_OPTIONS [B.3.1.8] for details regarding the possible debug options to set.

This function is typically called at the beginning of the application, after the call to WDC_DriverOpen() [B.3.2], and can be re-called at any time while the WDC library is in use (i.e., WDC_DriverClose() [B.3.3] has not been called) in order to change the debug settings.

Until the function is called, the WDC library uses the default debug options — see WDC_DBG_DEFAULT [B.3.1.8].

When the function is recalled, it performs any required cleanup for the previous debug settings and sets the default debug options before attempting to set the new options specified by the caller.

Prototype

```
DWORD DLLCALLCONV WDC_SetDebugOptions(
    WDC_DBG_OPTIONS dbgOptions,
    const CHAR *sDbgFile);
```

Parameters

Name	Type	Input/Output
dbgOptions	WDC_DBG_OPTIONS	Input
sDbgFile	const CHAR*	Input

Description

Name	Description
dbgOptions	A bit mask of flags indicating the desired debug settings — see `WDC_DBG_OPTIONS` [B.3.1.8]. If this parameter is set to zero, the default debug options will be used — see `WDC_DBG_DEFAULT` [B.3.1.8].
sDbgFile	WDC debug output file. This parameter is relevant only if the `WDC_DBG_OUT_FILE` flag is set in the debug options (`dbgOptions`) (either directly or via one of the convenience debug options combinations — see `WDC_DBG_OPTIONS` [B.3.1.8]). If the `WDC_DBG_OUT_FILE` debug flag is set and `sDbgFile` is `NULL`, WDC debug messages will be logged to the default debug file — **stderr**.

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.3.56. WDC_Err()

Purpose

Displays debug error messages according to the WDC debug options — see `WDC_DBG_OPTIONS` [B.3.1.8] and `WDC_SetDebugOptions`() [B.3.55].

Prototype

```
void DLLCALLCONV WDC_Err(
    const CHAR *format
    [, argument] ...);
```

Parameters

Name	Type	Input/Output
format	const CHAR*	Input
argument		Input

Description

Name	Description
format	Format-control string, which contains the error message to display. The string is limited to 256 characters (CHAR)
argument	Optional arguments for the format string

Return Value

None

B.3.57. WDC_Trace()

Purpose

Displays debug trace messages according to the WDC debug options — see `WDC_DBG_OPTIONS` [B.3.1.8] and `WDC_SetDebugOptions`() [B.3.55].

Prototype

```
void DLLCALLCONV WDC_Trace(
    const CHAR *format
    [, argument] ...);
```

Parameters

Name	Type	Input/Output
format	const CHAR*	Input
argument		Input

Description

Name	Description
format	Format-control string, which contains the trace message to display. The string is limited to 256 characters (CHAR)
argument	Optional arguments for the format string

Return Value

None

B.3.58. WDC_GetWDHandle()

Purpose

Returns a handle to WinDriver's kernel module, which is required by the basic `WD_xxx` WinDriver PCI/ISA API, described in the **WinDriver PCI Low-Level API Reference** (see Remarks below).

Prototype

```
HANDLE DLLCALLCONV WDC_GetWDHandle(void);
```

Return Value

Returns a handle to WinDriver's kernel module, or `INVALID_HANDLE_VALUE` in case of a failure

Remarks

- When using only the WDC API, you do not need to get a handle to WinDriver, since the WDC library encapsulates this for you. This function enables you to get the WinDriver handles used by the WDC library so you can pass it to low-level `WD_xxx` API, if such APIs are used from your code. In such cases, take care **not** to close the handle you received (using `WD_Close`()). The handle will be closed by the WDC library when it is closed, using `WDC_DriverClose`() [B.3.3]. The low-level `WD_xxx` API is described in the **WinDriver PCI Low-Level API Reference**.

B.3.59. WDC_GetDevContext()

Purpose

Returns the device's user context information.

Prototype

```
PVOID DLLCALLCONV WDC_GetDevContext(WDC_DEVICE_HANDLE hDev);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input

Description

Name	Description
hDev	Handle to a WDC device, returned by `WDC_xxxDeviceOpen()` (PCI [B.3.17] / ISA [B.3.18])

Return Value

Returns a pointer to the device's user context, or `NULL` if no context has been set.

B.3.60. WDC_GetBusType()

Purpose

Returns the device's bus type: `WD_BUS_PCI`, `WD_BUS_ISA` or `WD_BUS_UNKNOWN`.

Prototype

```
WD_BUS_TYPE DLLCALLCONV WDC_GetBusType(WDC_DEVICE_HANDLE hDev);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input

Description

Name	Description
hDev	Handle to a WDC device, returned by `WDC_xxxDeviceOpen()` (PCI [B.3.17] / ISA [B.3.18])

Return Value

Returns the device's bus type [B.7.1].

B.3.61. WDC_Sleep()

Purpose

Delays execution for the specified duration of time (in microseconds).
By default the function performs a busy sleep (consumes CPU cycles).

Prototype

```
DWORD DLLCALLCONV WDC_Sleep(
    DWORD dwMicroSecs,
    WDC_SLEEP_OPTIONS options);
```

Parameters

Name	Type	Input/Output
dwMicroSecs	DWORD	Input
options	WDC_SLEEP_OPTIONS	Input

Description

Name	Description
dwMicroSecs	The number of microseconds to sleep
options	Sleep options [B.3.1.7]

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.3.62. WDC_Version()

Purpose

Returns the version number of the WinDriver kernel module used by the WDC library.

Prototype

```
DWORD DLLCALLCONV WDC_Version(
    CHAR *sVersion,
    DWORD *pdwVersion);
```

Parameters

Name	Type	Input/Output
sVersion	CHAR*	Output
pdwVersion	DWORD*	Output

Description

Name	Description
sVersion	Pointer to a pre-allocated buffer to be filled by the function with the driver's version information string. The size of the version string buffer must be at least 128 bytes (characters).
pdwVersion	Pointer to a value indicating the version number of the WinDriver kernel module used by the WDC library

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.4. WDC Low-Level API

This section described the WDC types and preprocessor definitions defined in the **WinDriver/include/wdc_defs.h** header file.

B.4.1. WDC_ADDR_DESC Structure

PCI/ISA device memory or I/O address space information structure.

Field	Type	Description
dwAddrSpace	DWORD	The address space number
fIsMemory	BOOL	• **TRUE**: memory address space. • **FALSE**: I/O address space.
dwItemIndex	DWORD	The index of the `WD_ITEMS` structure [B.7.6] for the address space, which is retrieved and stored by `WDC_xxxDeviceOpen`() in the `cardReg.Card.Item` array of the relevant WDC device information structure [B.4.2]
dwBytes	DWORD	The address space's size (in bytes)
pAddr	KPTR	The kernel-mode mapping of the address space's physical base address. This address is used by the WDC API for accessing a memory or I/O region using the low-level `WD_Transfer`() or `WD_MultiTransfer`() APIs (described in the **WinDriver PCI Low-Level API Reference**), or when accessing memory address directly in the kernel.
pUserDirectMemAddr	UPTR	The user-mode mapping of a memory address space's physical base address. This address is used for accessing memory addresses directly from the user mode.

B.4.2. WDC_DEVICE Structure

PCI/ISA device information structure.
The `WDC_xxxDeviceOpen`() functions (PCI [B.3.17] / ISA [B.3.18]) allocate and return device structures of this type.

Field	Type	Description
id	WD_PCI_ID	Device ID information structure (relevant for PCI devices) — see [B.7.3]
slot	WD_PCI_SLOT	Device location information structure — see description of `WD_PCI_SLOT` in Section B.7.4
dwNumAddrSpaces	DWORD	Number of address spaces found on the device

Field	Type	Description
pAddrDesc	WDC_ADDR_DESC*	Array of memory and I/IO address spaces information structures [B.4.1]
cardReg	WD_CARD_REGISTER	WinDriver device resources information structure, returned by the low-level `WD_CardRegister`() function (see the **WinDriver PCI Low-Level API Reference**), which is called by the `WDC_xxxDeviceOpen`() functions
kerPlug	WD_KERNEL_PLUGIN	Kernel PlugIn driver information structure [B.9.1]. This structure is filled by the functions used to open a handle to a Kernel PlugIn for a `WDC_DEVICE` [12.5] — either `WDC_KernelPlugInOpen`() [B.3.22], or one of the `WDC_xxxDeviceOpen`() functions (PCI [B.3.17] / ISA [B.3.18]) when called with the name of a Kernel PlugIn driver — and is maintained by the WDC library. If no Kernel PlugIn handle was opened for the device, this structure is not used.
Int	WD_INTERRUPT	Interrupt information structure. This structure is filled by the `WDC_xxxDeviceOpen`() functions for devices that have interrupts, and is maintained by the WDC library.
hIntThread	DWORD	Handle to the interrupt thread that is spawn when interrupts are enabled. This handle is passed by WDC to the low-level WinDriver interrupt APIs. When using the WDC API you do not need to access this handle directly.

Field	Type	Description
Event	WD_EVENT	WinDriver Plug-and-Play and power management events information structure — see `EventRegister()` description in the **WinDriver PCI Low-Level API Reference** for details.
hEvent	HANDLE	Handle used by the WinDriver `EventRegister()` / `EventUnregister()` functions (see the **WinDriver PCI Low-Level API Reference**) When using the WDC API you do not need to access this handle directly.
pCtx	PVOID	Device context information. This information is received as a parameter by the `WDC_xxxDeviceOpen()` functions and stored in the device structure for future use by the calling application (optional)

B.4.3. PWDC_DEVICE

Pointer to a `WDC_DEVICE` structure [B.4.2].

```
typedef WDC_DEVICE *PWDC_DEVICE
```

The **wdc_defs.h** macros cast WDC device pointer parameters (`pDev`) to `PWDC_DEVICE`. You may also pass `WDC_DEVICE_HANDLE` [B.3.1.1] variables for such parameters.

B.4.4. WDC_MEM_DIRECT_ADDR Macro

Purpose

Utility macro that returns a pointer that can be used for direct access to a specified memory address space from the context of the calling process.

Prototype

```
WDC_MEM_DIRECT_ADDR(pAddrDesc)
```

Parameters

Name	Type	Input/Output
pAddrDesc	WDC_ADDR_DESC*	Input

Description

Name	Description
pAddrDesc	Pointer to a WDC memory address space information structure [B.4.1]

Return Value

When called from the user mode, returns the user-mode mapping of the physical memory address (`pAddrDesc->pUserDirectMemAddr`);
When called from the kernel mode, returns the kernel-mode mapping of the physical memory address (`pAddrDesc->pAddr`).
The returned pointer can be used for accessing the memory directly from the user mode or kernel mode, respectively.

B.4.5. WDC_ADDR_IS_MEM Macro

Purpose

Utility macro that checks if a given address space is a memory or I/O address space.

Prototype

```
WDC_ADDR_IS_MEM(pAddrDesc)
```

Parameters

Name	Type	Input/Output
pAddrDesc	WDC_ADDR_DESC*	Input

Description

Name	Description
pAddrDesc	Pointer to a WDC memory address space information structure [B.4.1]

Return Value

Returns `pAddrDesc->fIsMemory`, which is set to `TRUE` for a memory address space and to `FALSE` otherwise.

B.4.6. WDC_GET_ADDR_DESC Macro

Purpose

Utility macro that retrieves a WDC address space information structure (`WDC_ADDR_DESC` [B.4.1]), which complies to the specified address space number.

Prototype

```
WDC_GET_ADDR_DESC(
    pDev,
    dwAddrSpace)
```

Parameters

Name	Type	Input/Output
pDev	PWDC_DEVICE	Input
dwAddrSpace	DWORD	Input

Description

Name	Description
pDev	Pointer to a WDC device information structure [B.4.3]
dwAddrSpace	Address space number

Return Value

Returns a pointer to the device's address information structure (`WDC_ADDR_DESC` [B.4.1]) for the specified address space number — `pDev->pAddrDesc[dwAddrSpace]`.

B.4.7. WDC_GET_ADDR_SPACE_SIZE Macro

Purpose

Utility macro that retrieves a WDC address space size

Prototype

```
WDC_GET_ADDR_DESC(
    pDev,
    dwAddrSpace)
```

Parameters

Name	Type	Input/Output
pDev	PWDC_DEVICE	Input
dwAddrSpace	DWORD	Input

Description

Name	Description
pDev	Pointer to a WDC device information structure [B.4.3]
dwAddrSpace	Address space number

Return Value

Returns the size of the specified address space number

B.4.8. WDC_GET_ENABLED_INT_TYPE Macro

Purpose

Utility macro for retrieving the value of a WDC device's **`dwEnabledIntType`** `WD_INTERRUPT` field. This field is updated by `WDC_IntEnable`() [B.3.48] to indicate the interrupt type enabled for the device, as detailed in the description of the macro's return value below.

Prototype

```
WDC_GET_ENABLED_INT_TYPE(pDev)
```

Parameters

Name	Type	Input/Output
pDev	PWDC_DEVICE	Input

Description

Name	Description
pDev	Pointer to a WDC device information structure [B.4.3]

Return Value

Returns the interrupt type enabled for the device:

- **`INTERRUPT_MESSAGE_X`** — Extended Message-Signaled Interrupts (MSI-X)
- **`INTERRUPT_MESSAGE`** — Message-Signaled Interrupts (MSI)
- **`INTERRUPT_LEVEL_SENSITIVE`** — Legacy level-sensitive interrupts
- **`INTERRUPT_LATCHED`** — Legacy edge-triggered interrupts.
  The value of this flag is zero and it is applicable only when no other interrupt flag is set.

Remarks

- The Windows APIs do not distinguish between MSI and MSI-X; therefore, on this OS the WinDriver functions set the **`INTERRUPT_MESSAGE`** flag for both MSI and MSI-X.
- Call this macro only after calling `WDC_IntEnable`() [B.3.48] to enable interrupts on your PCI card.
- This macro is normally relevant only in the case of PCI devices that support more than one type of interrupt.
- You can pass the returned value to the `WDC_INT_IS_MSI` macro to check if MSI or MSI-X was enabled [B.4.10].

B.4.9. WDC_GET_INT_OPTIONS Macro

Purpose

Utility macro for retrieving the value of a WDC device's interrupt options, which indicate the types of interrupts supported by the device, as detailed in the description of the macro's return value below.

Prototype

```
WDC_GET_INT_OPTIONS(pDev)
```

Parameters

Name	Type	Input/Output
pDev	PWDC_DEVICE	Input

Description

Name	Description
pDev	Pointer to a WDC device information structure [B.4.3]

Return Value

Returns a bit-mask indicating the types of interrupts supported by the device:

- **`INTERRUPT_MESSAGE_X`**: Extended Message-Signaled Interrupts (MSI-X).
- **`INTERRUPT_MESSAGE`**: Message-Signaled Interrupts (MSI).
- **`INTERRUPT_LEVEL_SENSITIVE`**: Legacy level-sensitive interrupts.
- **`INTERRUPT_LATCHED`**: Legacy edge-triggered interrupts.
  The value of this flag is zero and it is applicable only when no other interrupt flag is set.

Remarks

- You can pass the returned options to the `WDC_INT_IS_MSI` macro to check whether they include the `INTERRUPT_MESSAGE` (MSI) and/or `INTERRUPT_MESSAGE_X` (MSI-X) flags [B.4.10].

B.4.10. WDC_INT_IS_MSI Macro

Purpose

Utility macro that checks whether a given interrupt type bit-mask contains the Message-Signaled Interrupts (MSI) or Extended Message-Signaled Interrupts (MSI-X) interrupt type flags.

Prototype

```
WDC_INT_IS_MSI(dwIntType)
```

Parameters

Name	Type	Input/Output
dwIntType	DWORD	Input

Description

Name	Description
dwIntType	Interrupt types bit-mask

Return Value

Returns TRUE if the provided interrupt type bit-mask includes the **INTERRUPT_MESSAGE** (MSI) and/or **INTERRUPT_MESSAGE_X** (MSI-X) flags; otherwise returns FALSE.

B.4.11. WDC_GET_ENABLED_INT_LAST_MSG Macro

Purpose

Utility macro that retrieves the message data of the last received interrupt for the Message-Signaled Interrupts (MSI) / Extended Message-Signaled Interrupts (MSI-X) enabled for the device (on Linux and Windows 7 and higher).

Prototype

```
WDC_GET_ENABLED_INT_LAST_MSG(pDev)
```

Parameters

Name	Type	Input/Output
pDev	PWDC_DEVICE	Input

Description

Name	Description
pDev	Pointer to a WDC device information structure [B.4.3]

Return Value

If MSI or MSI-X was enabled for the given device, the macro returns the message data of the last message received for the device's interrupt; otherwise returns zero.

B.4.12. WDC_IS_KP Macro

Purpose

Utility macro that checks whether a WDC device uses a Kernel PlugIn driver.

Prototype

```
WDC_IS_KP(pDev)
```

Parameters

Name	Type	Input/Output
pDev	PWDC_DEVICE	Input

Description

Name	Description
pDev	Pointer to a WDC device information structure [B.4.3]

Return Value

Returns TRUE if the device uses a Kernel PlugIn driver; otherwise returns FALSE.

B.5. WDS Library Overview

The *"WinDriver Shared"* — **WDS** — API provides convenient user-mode wrappers to the basic WinDriver Shared WD_xxx API, which is described in the **WinDriver PCI Low-Level API Reference**.

The WDS wrappers are designed to simplify the usage of WinDriver. While you can still use the basic WD_xxx WinDriver API from your code, we recommend that you refrain from doing so and use the high-level WDS API instead.

NOTE: Some of the WDS API can be used both from the user mode and from the kernel mode (from a Kernel PlugIn driver [11]).

The pci_diag sample utilize the WDS API, it also uses it through the high-level diagnostics code (**wds_diag_lib/.c/.h**).

The WDS API is part of **wdapi1281** DLL/shared object:
WinDriver\redist\wdapi1281.dll (Windows) / **WinDriver/lib/libwdapi1281.so** (Linux).
The source code for the WDS API is found in the **WinDriver/src/wdapi** directory.

The WDS interface is provided in the **wds_lib.h** (found under the **WinDriver/includes** directory).

- [**wds_lib.h**] declares the "high-level" WDS API (type definitions, function declarations, etc.).

The following sections describe the WDS high-level [B.6].

B.6. WDS High-Level API

This section describes the WDS API defined in the **WinDriver/include/wds_lib.h** header file.

B.6.1. WDS_SharedBufferAlloc()

Purpose

Allocates a memory buffer that can be shared between the user mode and the kernel mode (**"shared buffer"**), and returns user-mode and kernel-mode virtual address space mappings of the allocated buffer.

This function provides a useful method for sharing data between a user-mode application and a Kernel PlugIn driver.

Prototype

```
DWORD DLLCALLCONV WDS_SharedBufferAlloc(
    UINT64 qwBytes,
    DWORD dwOptions,
    WD_KERNEL_BUFFER **ppBuf);
```

Parameters

Name	Type	Input/Output
qwBytes	UINT64	Input
dwOptions	DWORD	Input
ppBuf	WD_KERNEL_BUFFER**	Output

Description

Name	Description
qwBytes	The size of the buffer to allocate, in bytes
dwOptions	Kernel buffer options bit-mask, which can consist of a combination of the enumeration values listed below. • **KER_BUF_ALLOC_NON_CONTIG**:Allocates a non contiguous buffer • **KER_BUF_ALLOC_CONTIG**:Allocates a physically contiguous buffer • **KER_BUF_ALLOC_CACHED**:Allocates a cached buffer. This option can be set with KER_BUF_ALLOC_NON_CONTIG or KER_BUF_ALLOC_CONTIG buffer
ppBuf	Pointer to a WD_KERNEL_BUFFER [B.7.11] pointer, to be filled by the function. The caller should use *ppBuf->pUserAddr usermode mapped address. When the buffer is no longer needed, (`*ppBuf`) should be passed to `WDS_SharedBufferFree`() [B.6.2].

The KER_BUF_ALLOC_NON_CONTIG option is valid only as part of "WinDriver for Server" API and requires "WinDriver for Server" license. Note that "WinDriver for Server" APIs are included in WinDriver evaluation version.

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

Remarks

- This function is currently only supported from the user mode.
- This function is supported only for Windows and Linux.

B.6.2. WDS_SharedBufferFree()

Purpose

Frees a shared buffer that was allocated by a previous call to `WDS_SharedBufferAlloc`() [B.6.1].

Prototype

```
DWORD DLLCALLCONV WDS_SharedBufferFree(
    WD_KERNEL_BUFFER *pBuf);
```

Parameters

Name	Type	Input/Output
pBuf	WD_KERNEL_BUFFER *	Input

Description

Name	Description
pBuf	Pointer to a WD_KERNEL_BUF [B.7.11] structure, received within the `*ppBuf` parameter of a previous call to `WDS_SharedBufferAlloc`() [B.6.1]

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

Remarks

- This function is currently only supported from the user mode.
- This function is supported only for Windows and Linux.

B.6.3. WDS_SharedBufferGet()

Purpose

Retrieves a shared buffer which was allocated by another process.

This API is not part of the standard WinDriver APIs, and is not included in the standard version of WinDriver. It is part of "WinDriver for Server" API and requires "WinDriver for Server" license. Note that "WinDriver for Server" APIs are included in WinDriver evaluation version.

Prototype

```
DWORD DLLCALLCONV WDS_SharedBufferGet(
    DWORD hKerBuf,
    WD_KERNEL_BUFFER **ppKerBuf);
```

Before calling this API, the calling process should recieve the global buffer handle via WinDriver IPC mechanism from the process that allocated the buffer.

Once the process finish using the shared buffer, it should release it using the regular free method- `WDS_SharedBufferFree`() [B.6.2].

Parameters

Name	Type	Input/Output
hKerBuf	DWORD	Input
ppKerBuf	WD_KERNEL_BUFFER**	Output

Description

Name	Description
hKerBuf	Kernel buffer handle.
ppKerBuf	Pointer to a pointer to a kernel buffer information structure [B.7.11], which is associated with hKerBuf.

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.6.4. WDS_SharedBufferGetGlobalHandle Macro

Purpose

Utility macro that returns a kernel buffer global handle that can be used for buffer sharing between multiple processes.

Prototype

```
WDS_SharedBufferGetGlobalHandle(pKerBuf)
```

Parameters

Name	Type	Input/Output
pKerBuf	WD_KERNEL_BUFFER*	Input

Description

Name	Description
pKerBuf	Pointer to a kernel buffer information structure [B.7.11]

Return Value

Kernel buffer handle of pKerBuf.

B.7. WD_xxx Structures, Types and General Definitions

This section describes basic `WD_xxx` structures and types, which are used by the `WDC_xxx` & `WDS_xxx` APIs. The APIs described in this section are defined in the **WinDriver/include/windrvr.h** header file.

B.7.1. WD_BUS_TYPE Enumeration

Bus types enumeration.

Enum Value	Description
WD_BUS_USB	Universal Serial Bus (USB)
WD_BUS_UNKNOWN	Unknown bus
WD_BUS_ISA	ISA bus
WD_BUS_EISA	EISA (ISA Plug-and-Play) bus
WD_BUS_PCI	PCI bus

B.7.2. ITEM_TYPE Enumeration

Enumeration of card item types.

Enum Value	Description
ITEM_NONE	Unknown item type
ITEM_INTERRUPT	Interrupt item
ITEM_MEMORY	Memory item
ITEM_IO	I/O item
ITEM_BUS	Bus item

B.7.3. WD_PCI_ID Structure

PCI device identification information structure.

Field	Type	Description
dwVendorId	DWORD	Vendor ID
dwDeviceId	DWORD	Device ID

B.7.4. WD_PCI_SLOT Structure

PCI device location information structure.

Field	Type	Description
dwBus	DWORD	PCI Bus number (0 based)
dwSlot	DWORD	Slot number (0 based)
dwFunction	DWORD	Function number (0 based)

B.7.5. WD_PCI_CAP Structure

PCI capability information structure.

Field	Type	Description
dwCapId	DWORD	PCI capability ID
dwCapOffset	DWORD	PCI capability register offset

B.7.6. WD_ITEMS Structure

Card resources information structure.

Field	Type	Description
item	DWORD	Item type — see the `ITEM_TYPE` enumeration [B.7.2]. This field is updated by the `WDC_PciGetDeviceInfo`() function [B.3.16], or the low-level`WD_PciGetCardInfo`() functions (see the **WinDriver PCI Low-Level API Reference**).
fNotSharable	DWORD	• **1** — Non-sharable resource; should be locked for exclusive use • **0** — Sharable resource This field is updated by the `WDC_PciGetDeviceInfo`() function [B.3.16] or the low-level `WD_PciGetCardInfo`() function, and can be modified manually before registering the resources using the `WDC_xxxDeviceOpen`() functions (PCI [B.3.17] / ISA [B.3.18]) or the low-level `WD_CardRegister`() function; (the low-level functions are documented in the **WinDriver PCI Low-Level API Reference**).

Field	Type	Description
I	union	Union of resources data, based on the item's type (**`item`**)
• Mem	struct	Memory-item descriptor (**`item`**=`ITEM_MEMORY`)
* pPhysicalAddr	PHYS_ADDR	First address of the physical memory range. For Plug-and-Play hardware (PCI) this field is updated by the `WDC_PCIGetDeviceInfo`() function [B.3.16] or the low-level `WD_PciGetCardInfo`() function (see the **WinDriver PCI Low-Level API Reference**). NOTE: In the case of a 64-bit memory BAR the value set in this field by may be incorrect, due to the 32-bit field size. For this reason, `WDC_PciDeviceOpen`() [B.3.17] ignores this field and retrieves the physical address directly from the card (as does the low-level `WD_CardRegister`() function).
* qwBytes	UINT64	Length (in bytes) of the memory range. This field is updated by the `WDC_PciGetDeviceInfo`() function [B.3.16] or the low-level `WD_PciGetCardInfo`() function (see the **WinDriver PCI Low-Level API Reference**).
* pTransAddr	KPTR	Kernel-mode mapping of the memory range's physical base address. This field is updated by `WD_CardRegister`() (see the **WinDriver PCI Low-Level API Reference**), which is called from the `WDC_xxxDeviceOpen`() functions (PCI [B.3.17] / ISA [B.3.18]).
* pUserDirectAddr	UPTR	User-mode mapping of the memory range's physical base address. This field is updated by `WD_CardRegister`() (see the **WinDriver PCI Low-Level API Reference**), which is called from the `WDC_xxxDeviceOpen`() functions (PCI [B.3.17] / ISA [B.3.18]).
* dwBar	DWORD	Base Address Register (BAR) number. This field is updated by the `WDC_PciGetDeviceInfo`() function [B.3.16] or the low-level `WD_PciGetCardInfo`() function (see the **WinDriver PCI Low-Level API Reference**).
* pReserved	KPTR	Reserved for internal use

Field	Type	Description
* dwOptions	DWORD	A bit-mask of memory-item registration flags, applicable when calling one of the `WDC_xxxDeviceOpen`() functions (PCI [B.3.17] / ISA [B.3.18]) or the low-level `WD_CardRegister`() function (see the **WinDriver PCI Low-Level API Reference**) — a combination of any of the of the following `WD_ITEM_MEM_OPTIONS` enumeration values: • **`WD_ITEM_MEM_DO_NOT_MAP_KERNEL`**: Avoid mapping the item's physical memory to the kernel address space (`I.Mem.pTransAddr` not set); map the memory only to the user-mode virtual address space (mapped base address: `I.Mem.pUserDirectAddr`). For more information, refer to Remark 2 in the documentation of `WDC_PciDeviceOpen`() [B.3.17]; (a similar remark is found in the documentation of the other device-open functions). NOTE: This flag is applicable only to memory items. • **`WD_ITEM_MEM_ALLOW_CACHE`** (Windows): Map the item's physical memory (base address: `I.Mem.pPhysicalAddr`) as cached. NOTE: This flag is applicable only to memory items that pertain to the host's RAM, as opposed to local memory on the card.

Field	Type	Description
• IO	struct	I/O-item descriptor (**item**=ITEM_IO)
* pAddr	KPTR	First address of the I/O range. This field is updated by the WDC_PciGetDeviceInfo() function [B.3.16] or the low-level WD_PciGetCardInfo() function (see the **WinDriver PCI Low-Level API Reference**).
* dwBytes	DWORD	Length (in bytes) of the I/O range. This field is updated by the WDC_PciGetDeviceInfo() function [B.3.16] or the low-level WD_PciGetCardInfo() function (see the **WinDriver PCI Low-Level API Reference**).
* dwBar	DWORD	Base Address Register (BAR) number. This field is updated by the WDC_PciGetDeviceInfo() function [B.3.16] or the low-level WD_PciGetCardInfo() function (see the **WinDriver PCI Low-Level API Reference**).
• Int	struct	Interrupt-item descriptor (**item**=ITEM_INTERRUPT)
* dwInterrupt	DWORD	Physical interrupt request (IRQ) number. This field is updated by the WDC_PciGetDeviceInfo() function [B.3.16] or the low-level WD_PciGetCardInfo() function (see the **WinDriver PCI Low-Level API Reference**).

Field	Type	Description
* dwOptions	DWORD	Interrupt bit-mask, which can consist of a combination of any of the following flags: **Interrupt type flags:** • **INTERRUPT_MESSAGE_X** — Indicates that the hardware supports Extended Message-Signaled Interrupts (MSI-X). This option is applicable only to PCI cards on Linux — see information in Section 9.2.4. • **INTERRUPT_MESSAGE** — On Linux, indicates that the hardware supports Message-Signaled Interrupts (MSI). On Windows, indicates that the hardware supports MSI or MSI-X. This option is applicable only to PCI cards on Linux and Windows 7 and higher — see information in Section 9.2.4. • **INTERRUPT_LEVEL_SENSITIVE** — Indicates that the hardware supports level-sensitive interrupts. • **INTERRUPT_LATCHED** — indicates that the device supports legacy edge-triggered interrupts. The value of this flag is zero, therefore it is applicable only when no other interrupt flag is set. **NOTE:** For Plug-and-Play hardware (PCI), use WinDriver's `WDC_PciGetDeviceInfo`() [B.3.16] (or the low-level `WD_PciGetCardInfo`() function) to retrieve the Plug-and-Play hardware information, including the supported interrupt types. For non-Plug-and-Play hardware, the relevant interrupt type flag (normally — `INTERRUPT_LATCHED`) should be set by the user in the call to `WDC_IsaDeviceOpen`() or to the low-level `WD_CardRegister`() function. **Miscellaneous interrupt options:**

Field	Type	Description
* hInterrupt	DWORD	Handle to an internal WinDriver interrupt structure, required by the low-level `WD_xxx`() WinDriver interrupt APIs (see the **WinDriver PCI Low-Level API Reference**). This field is updated by `WD_CardRegister`() (see the **WinDriver PCI Low-Level API Reference**), which is called from the `WDC_xxxDeviceOpen`() functions (PCI [B.3.17] / ISA [B.3.18]).
* dwReserved1	DWORD	Reserved for internal use
* pReserved2	KPTR	Reserved for internal use
• Bus	WD_BUS	Bus-item descriptor (**`item`**=`ITEM_BUS`)
* dwBusType	WD_BUS_TYPE	Device's bus type — see the `WD_BUS_TYPE` enumeration [B.7.1]
* dwBusNum	DWORD	Bus Number
* dwSlotFunc	DWORD	Slot/socket and function information for the device: The lower three bits represent the function number and the remaining bits represent the slot/socket number. For example: a value of 0x80 (<=> 10000000 binary) corresponds to a function number of 0 (lower 3 bits: 000) and a slot/socket number of 0x10 (remaining bits: 10000). This field is updated by the `WDC_PciGetDeviceInfo`() function [B.3.16] or the low-level `WD_PciGetCardInfo`() function (see the **WinDriver PCI Low-Level API Reference**).

B.7.7. WD_CARD Structure

Card information structure.

Field	Type	Description
dwItems	DWORD	Number of items (resources) on the card
Item	WD_ITEMS [WD_CARD_ITEMS]	Array of card resources (items) information structures [B.7.6]

B.7.8. WD_PCI_CARD_INFO Structure

PCI card information structure.

Field	Type	Description
pciSlot	WD_PCI_SLOT	PCI device location information structure [B.7.4], which can be acquired by calling `WDC_PciScanDevices`() [B.3.4] (or the low-level `WD_PciScanCards`() function — see the **WinDriver PCI Low-Level API Reference**)
Card	WD_CARD	Card information structure [B.7.7]

B.7.9. WD_DMA Structure

Direct Memory Access (DMA) information structure.

Field	Type	Description
hDma	DWORD	DMA buffer handle (or 0 for a failed allocation). This handle is returned from `WDC_DMAContigBufLock()` [B.3.40] and `WDC_DMASGBufLock()` [B.3.41] (or from the low-level `WD_DMALock()` function — see the **WinDriver PCI Low-Level API Reference**)
pUserAddr	PVOID	User-mode mapped address of the DMA buffer. This mapping is returned from `WDC_DMAContigBufLock()` [B.3.40] and `WDC_DMASGBufLock()` [B.3.41] (in this function the `pBuf` user-mode buffer provided by the caller is used), or from the low-level `WD_DMALock()` function (see the **WinDriver PCI Low-Level API Reference**). Note: if the `DMA_KERNEL_ONLY` flag was set in the DMA options bit-mask field (**`dwOptions`**), this field is not updated.
pKernelAddr	KPTR	Kernel-mode mapped address of the DMA buffer. This mapping is returned from `WDC_DMAContigBufLock()` [B.3.40] and `WDC_DMASGBufLock()` [B.3.41] (on Windows), or from the low-level `WD_DMALock()` function (for contiguous-buffer DMA and for Scatter/Gather DMA on Windows — see the **WinDriver PCI Low-Level API Reference**)
dwBytes	DWORD	The size of the DMA buffer (in bytes)
dwOptions	DWORD	DMA options bit-mask, which can consist of a combination of any of the enumeration values listed below. **NOTE:** Options that are also applicable to the `WDC_DMASGBufLock()` and `WDC_DMAContigBufLock()` functions (according to the descriptions below) should be set within these functions' `dwOptions` parameter. The `dwOptions` field of the `WD_DMA` structure returned by these functions will be updated accordingly. DMA flags:

Field	Type	Description
		• **DMA_FROM_DEVICE**: Synchronize the DMA buffer for transfers from the device to memory. • **DMA_TO_DEVICE**: Synchronize the DMA buffer for transfers from memory to the device. • **DMA_TO_FROM_DEVICE**: Synchronize the DMA buffer for transfers in both directions — i.e., from the device to memory and from memory to the device (<=> DMA_FROM_DEVICE | DMA_TO_DEVICE). • **DMA_KERNEL_BUFFER_ALLOC**: Allocate a contiguous DMA buffer in the physical memory. The default behavior (when this flag is not set) is to allocate a Scatter/Gather DMA buffer. Set this flag when calling the low-level WD_DMALock() function to allocate a contiguous DMA buffer (see the **WinDriver PCI Low-Level API Reference**). When using the WDC APIs there is no need to set this flag, since WDC_DMAContigBufLock() [B.3.40] sets it automatically, and WDC_DMASGBufLock() [B.3.41] is used to allocate Scatter/Gather DMA buffers, for which this flag is not applicable. • **DMA_KBUF_BELOW_16M**: Allocate the physical DMA buffer within the first 16MB of the main memory. This flag is applicable only to contiguous-buffer DMA — i.e., when calling WDC_DMAContigBufLock() [B.3.40] or when calling the low-level WD_DMALock() flag with the DMA_KERNEL_BUFFER_ALLOC flag (see the **WinDriver PCI Low-Level API Reference**).

Field	Type	Description
		• **DMA_LARGE_BUFFER**: Enable locking of a large DMA buffer — `dwBytes > 1MB`. This flag is applicable only to Scatter/Gather DMA. Set this flag when calling the low-level `WD_DMALock`() function to allocate a large DMA buffer (see the **WinDriver PCI Low-Level API Reference**). When using the WDC APIs there is no need to set this flag, since `WDC_DMASGBufLock`() [B.3.41] sets it automatically when called to allocate a large DMA buffer, and `WDC_DMAContigBufLock`() [B.3.40] is used to allocate contiguous DMA buffers, for which this flag is not applicable. • **DMA_ALLOW_CACHE**: Allow caching of the DMA buffer. • **DMA_KERNEL_ONLY_MAP**: Do not map the allocated DMA buffer to the user mode (i.e., map it to kernel-mode only). This flag is applicable only in cases where the `DMA_KERNEL_BUFFER_ALLOC` flag is applicable — see above. • **DMA_ALLOW_64BIT_ADDRESS**: Allow allocation of 64-bit DMA addresses. This flag is supported on Windows and Linux.
dwPages	DWORD	Number of physical memory blocks used for the allocated buffer. For contiguous-buffer DMA this field is always set to 1.
hCard	DWORD	Low-level WinDriver card handle, which is acquired by `WDC_xxxDeviceOpen`() (by calling `WD_CardRegister`() — see the **WinDriver PCI Low-Level API Reference**) and stored in the WDC device structure
Page	WD_DMA_PAGE [WD_DMA_PAGES]	Array of physical memory pages information structures. For contiguous buffer DMA this array always holds only one element (see `dwPages`).
• pPhysicalAddr	DMA_ADDR	The page's physical address
• dwBytes	DWORD	The page's size (in bytes)

B.7.10. WD_TRANSFER Structure

Memory/IO read/write transfer command information structure.

Field	Type	Description
cmdTrans	DWORD	A value indicating the type of transfer to perform — refer to the definition of the `WD_TRANSFER_CMD` enumeration in **windrvr.h**. The transfer command can be of either of the following types: • A read/write transfer command that conforms to the following format: **`<dir><p>_[S]<size>`** Explanation: **`<dir>`**: **`R`** for read, **`W`** for write **`<p>`**: **`P`** for I/O, **`M`** for memory **`<S>`**: signifies a string (block) transfer, as opposed to a single transfer **`<size>`**: BYTE, WORD, DWORD or QWORD • **`CMD_MASK`**: This command is applicable when passing interrupt transfer commands to the interrupt enable functions (`WDC_IntEnable`() [B.3.48] or the low-level `InterruptEnable`() or `WD_IntEnable`() functions — see the **WinDriver PCI Low-Level API Reference**). `CMD_MASK` is an interrupt mask command for determining the source of the interrupt: When this command is set, upon the arrival of an interrupt in the kernel WinDriver masks the value of the previous read command in the `WD_TRANSFER` commands array with the mask that is set in the relevant `Data` field union member of the mask transfer command. For example, for a `pTransCmds` `WD_TRANSFER` array, if `pTransCmds[i-1].cmdTrans` is `RM_BYTE`, WinDriver performs the following mask: `pTransCmds[i-1].Data.Byte & pTransCmds[i].Data.Byte`. If the mask is successful, the driver claims ownership of the interrupt and when the control is returned to the user mode, the interrupt handler routine that was passed to the interrupt enable function is invoked; otherwise, the driver rejects ownership of the interrupt, the interrupt handler routine is not invoked and the subsequent transfer commands in the array are not executed. (Acceptance and rejection of the interrupt is relevant only when handling legacy interrupts; since MSI/MSI-X interrupts are not shared, WinDriver will always accept control of such interrupts.) NOTE: A `CMD_MASK` command must be preceded by a read transfer command (`RM_XXX` / `RP_XXX`).

Field	Type	Description
pPort	KPTR	The I/O port address or the kernel-mapped virtual memory address, which has been stored in the relevant device (`WDC_DEVICE` [B.4.2]): `dev.pAddrDesc[i].pAddr` (where *i* is the index of the desired address space). (When using the low-level `WD_xxx`() APIs, these values are stored within the `pAddr` (I/O) and `pTransAddr` (memory) fields of the relevant `cardReg.Card.Item[i]` item — see the **WinDriver PCI Low-Level API Reference**).
dwBytes	DWORD	The number of bytes to transfer
fAutoinc	DWORD	Relevant only for string (block) transfers: If **`TRUE`**, the I/O or memory port/address will be incremented after each block that is transferred; If **`FALSE`**, all data is transferred to/from the same port/address.
dwOptions	DWORD	Must be zero
Data	union	The data buffer for the transfer (input for write commands, output for read commands):
• Byte	BYTE	Used for 8-bit transfers
• Word	WORD	Used for 16-bit transfers
• Dword	UINT32	Used for 32-bit transfers
• Qword	UINT64	Used for 64-bit transfers
• pBuffer	PVOID	Used for string (block) transfers — a pointer to the data buffer for the transfer

B.7.11. WD_KERNEL_BUFFER Structure

Kernel buffer information structure.

Field	Type	Description
hKerBuf	DWORD	Kernel buffer handle (or 0 for a failed allocation). This handle is returned from `WDS_SharedBufferAlloc`() [B.6.1] (or from the low-level `WD_KernelBufLock`() function — see the **WinDriver PCI Low-Level API Reference**)
dwOptions	DWORD	Kernel buffer options bit-mask, which can consist of a combination of any of the enumeration values listed below. • **`ALLOCATE_CONTIG_BUFFER`**:Allocates a physically contiguous buffer • **`ALLOCATE_CACHED_BUFFER`**:Allocates a cached buffer

Field	Type	Description
qwBytes	UINT64	The requested buffer size (in bytes)
pKernelAddr	KPTR	Kernel-mode mapped address of the kernel buffer. This mapping is returned from `WDS_SharedBufferAlloc()` [B.6.1], or from the low-level `WD_KernelBufLock()` function (see the **WinDriver PCI Low-Level API Reference**)
pUserAddr	UPTR	User-mode mapped address of the kernel buffer. This mapping is returned from `WDS_SharedBufferAlloc()` [B.6.1] (or from the low-level `WD_KernelBufLock()` function (see the **WinDriver PCI Low-Level API Reference**).

B.8. Kernel PlugIn Kernel-Mode Functions

The following functions are callback functions which are implemented in your Kernel PlugIn driver, and which will be called when their calling event occurs. For example: `KP_Init` [B.8.1] is the callback function that is called when the driver is loaded. Any code that you want to execute upon loading should be in this function.

`KP_Init` [B.8.1] sets the name of the driver and the `KP_Open` [B.8.2] function(s).

`KP_Open` [B.8.2] sets the rest of the driver's callback functions.

For example:

```
kpOpenCall->funcClose = KP_Close;
    kpOpenCall->funcCall = KP_Call;
    kpOpenCall->funcIntEnable = KP_IntEnable;
    kpOpenCall->funcIntDisable = KP_IntDisable;
    kpOpenCall->funcIntAtIrql = KP_IntAtIrql;
    kpOpenCall->funcIntAtDpc = KP_IntAtDpc;
    kpOpenCall->funcIntAtIrqlMSI = KP_IntAtIrqlMSI;
    kpOpenCall->funcIntAtDpcMSI = KP_IntAtDpcMSI;
    kpOpenCall->funcEvent = KP_Event;
```

As explained in Section 11.6.2.1, it is the convention of this reference guide to mark the Kernel PlugIn callback functions as `KP_<functionality>` — e.g., `KP_Open`. However, you are free to select any name that you wish for your Kernel PlugIn callback functions, apart from `KP_Init`. The generated DriverWizard Kernel PlugIn code, for example, uses the selected driver name in the callback function names (e.g., for a <MyKP> driver it creates callbacks named `KP_MyKP_Open`, `KP_MyKP_Call`, etc.).

B.8.1. KP_Init

Purpose

Kernel PlugIn initialization function.
This function is called when the Kernel PlugIn driver is loaded.
The function sets the name of the Kernel PlugIn driver and the `KP_Open` callback function(s) [B.8.2].

Prototype

```
BOOL __cdecl KP_Init(KP_INIT *kpInit);
```

Parameters

Name	Type	Input/Output
kpInit	KP_INIT*	Output

Description

Name	Description
kpInit	Pointer to a pre-allocated Kernel PlugIn initialization information structure [B.9.4], whose fields should be updated by the function

Return Value

`TRUE` if successful. Otherwise `FALSE`.

Remarks

You must define the `KP_Init` function in your code in order to link the Kernel PlugIn driver to WinDriver. `KP_Init` is called when the driver is loaded. Any code that you want to execute upon loading should be in this function.

Example

```
BOOL __cdecl KP_Init(KP_INIT *kpInit)
{
    /* Check if the version of the WinDriver Kernel
       PlugIn library is the same version
       as windrvr.h and wd_kp.h */
    if (kpInit->dwVerWD != WD_VER)
    {
        /* You need to recompile your Kernel PlugIn
           with the compatible version of the WinDriver
           Kernel PlugIn library, windrvr.h and wd_kp.h */
       return FALSE;
    }

    kpInit->funcOpen = KP_Open;
    kpInit->funcOpen_32_64 = KP_PCI_VIRT_Open_32_64;
    strcpy (kpInit->cDriverName, "KPDriver"); /* Up to 12 chars */

  return TRUE;
}
```

B.8.2. KP_Open

Purpose

Kernel PlugIn open function.
This function sets the rest of the Kernel PlugIn callback functions (`KP_Call` [B.8.4], `KP_IntEnable` [B.8.6], etc.) and performs any other desired initialization (such as allocating memory for the driver context and filling it with data passed from the user mode).
The returned driver context (`*ppDrvContext`) will be passed to rest of the Kernel PlugIn callback functions.

The `KP_Open` callback is called when the `WD_KernelPlugInOpen`() function (see the **WinDriver PCI Low-Level API Reference**) is called from the user mode — either directly (when using the low-level WinDriver API [B.2]), or via a call to a high-level WDC function. `WD_KernelPlugInOpen`() is called from the `WDC_KernelPlugInOpen`() [B.3.22], and from the `WDC_xxxDeviceOpen`() functions (PCI [B.3.17] / ISA [B.3.18]) when they are called with the name of a valid Kernel PlugIn driver (set in the `pcKPDriverName` parameter).

The `WDC_xxxDeviceOpen`() functions cannot be used to open a handle to a 64-bit Kernel PlugIn function from a 32-bit application. For this purpose, use `WDC_KernelPlugInOpen`() (or the low-level `WD_KernelPlugInOpen`() function).

The Kernel PlugIn driver can implement two types of KP_Open callback functions —

- A "standard" Kernel PlugIn open function, which is used whenever a user-mode application opens a handle to a Kernel PlugIn driver, *except* when a 32-bit applications opens a handle to a 64-bit driver.
  This callback function is set in the funcOpen field of the KP_INIT structure [B.9.4] that is passed as a parameter to KP_Init [B.8.1].

- A function that will be used when a 32-bit user-mode application opens a handle to a 64-bit Kernel PlugIn driver.
  This callback function is set in the funcOpen_32_64 field of the KP_INIT structure [B.9.4] that is passed as a parameter to KP_Init [B.8.1].

A Kernel PlugIn driver can provide either one or both of these KP_Open callbacks, depending on the target configuration(s).

The **KP_PCI** sample (**WinDriver/samples/pci_diag/kp_pci/kp_pci.c**) implements both types of KP_Open callbacks — KP_PCI_Open() (standard) and KP_PCI_Open_32_64() (for opening a handle to a 64-bit Kernel PlugIn from a 32-bit application).
The generated DriverWizard Kernel PlugIn code always implements a standard Kernel PlugIn open function — KP_XXX_Open(). When selecting the *32-bit application for a 64-bit Kernel PlugIn* DriverWizard code-generation option (see Figure 4.10), the wizard also implements a KP_XXX_Open_32_64() function, for opening a handle to a 64-bit Kernel PlugIn driver from a 32-bit application.

Prototype

```
BOOL __cdecl KP_Open(
    KP_OPEN_CALL *kpOpenCall,
    HANDLE hWD,
    PVOID pOpenData,
    PVOID *ppDrvContext);
```

Parameters

Name	Type	Input/Output
kpOpenCall	KP_OPEN_CALL	Input
hWD	HANDLE	Input
pOpenData	PVOID	Input
ppDrvContext	PVOID*	Output

Description

Name	Description
kpOpenCall	Structure to fill in the addresses of the KP_xxx callback functions [B.9.5]
hWD	The WinDriver handle that WD_KernelPlugInOpen() was called with
pOpenData	Pointer to data passed from user mode
ppDrvContext	Pointer to driver context data with which the KP_Close [B.8.3], KP_Call [B.8.4], KP_IntEnable [B.8.6] and KP_Event [B.8.5] functions will be called. Use this to keep driver-specific information that will be shared among these callbacks.

Return Value

TRUE if successful. If FALSE, the call to WD_KernelPlugInOpen() from the user mode will fail.

Example

```
BOOL __cdecl KP_Open(KP_OPEN_CALL *kpOpenCall, HANDLE hWD,
            PVOID pOpenData, PVOID *ppDrvContext)
{
    kpOpenCall->funcClose = KP_Close;
    kpOpenCall->funcCall = KP_Call;
    kpOpenCall->funcIntEnable = KP_IntEnable;
    kpOpenCall->funcIntDisable = KP_IntDisable;
    kpOpenCall->funcIntAtIrql = KP_IntAtIrql;
    kpOpenCall->funcIntAtDpc = KP_IntAtDpc;
    kpOpenCall->funcIntAtIrqlMSI = KP_IntAtIrqlMSI;
    kpOpenCall->funcIntAtDpcMSI = KP_IntAtDpcMSI;
    kpOpenCall->funcEvent = KP_Event;

    /* You can allocate driver context memory here: */
    *ppDrvContext = malloc(sizeof(MYDRV_STRUCT));
    return *ppDrvContext!=NULL;
}
```

B.8.3. KP_Close

Purpose

Called when `WD_KernelPlugInClose()` (see the **WinDriver PCI Low-Level API Reference**) is called from user mode.
The high-level `WDC_xxxDeviceClose()` functions (PCI [B.3.19] / ISA [B.3.20]) automatically call `WD_KernelPlugInClose()` for devices that contain an open Kernel PlugIn handle (see Section 12.5).

This functions can be used to perform any required clean-up for the Kernel PlugIn (such as freeing memory previously allocated for the driver context, etc.).

Prototype

```
void __cdecl KP_Close(PVOID pDrvContext);
```

`KP_FUNC_CLOSE` Kernel PlugIn callback function type.

Parameters

Name	Type	Input/Output
pDrvContext	PVOID	Input

Description

Name	Description
pDrvContext	Driver context data that was set by `KP_Open` [B.8.2]

Return Value

None

Example

```
void __cdecl KP_Close(PVOID pDrvContext)
{
   if (pDrvContext)
        free(pDrvContext); /* Free allocated driver context memory */
}
```

B.8.4. KP_Call

Purpose

Called when the user-mode application calls `WDC_CallKerPlug`() [B.3.23] (or the low-level `WD_KernelPlugInCall`() function — see the **WinDriver PCI Low-Level API Reference**).

This function is a message handler for your utility functions.

Prototype

```
void __cdecl KP_Call(
    PVOID pDrvContext,
    WD_KERNEL_PLUGIN_CALL
    *kpCall,
    BOOL fIsKernelMode);
```

`KP_FUNC_CALL` Kernel PlugIn callback function type.

Parameters

Name	Type	Input/Output
pDrvContext	PVOID	Input/Output
kpCall	WD_KERNEL_PLUGIN_CALL	
• dwMessage	DWORD	Input
• pData	PVOID	Input/Output
• dwResult	DWORD	Output
fIsKernelMode	BOOL	Input

Description

Name	Description
pDrvContext	Driver context data that was set by `KP_Open` [B.8.2] and will also be passed to `KP_Close` [B.8.3], `KP_IntEnable` [B.8.6] and `KP_Event` [B.8.5]
kpCall	Structure with user-mode information received from the `WDC_CallKerPlug`() [B.3.23] (or from the low-level `WD_KernelPlugInCall`() function — see the **WinDriver PCI Low-Level API Reference**) and/or with information to return back to the user mode [B.9.3]
fIsKernelMode	This parameter is passed by the WinDriver kernel — see the fIsKernelMode remark, below.

Return Value

None

Remarks

- Calling `WDC_CallKerPlug()` [B.3.23] (or the low-level `WD_KernelPlugInCall()` function — see the **WinDriver PCI Low-Level API Reference**) in the user mode will call your `KP_Call` [B.8.4] callback function in the kernel mode. The `KP_Call` function in the Kernel PlugIn will determine which routine to execute according to the message passed to it.

- The `fIsKernelMode` parameter is passed by the WinDriver kernel to the `KP_Call` routine. The user is not required to do anything about this parameter. However, notice how this parameter is passed in the sample code to the macro `COPY_TO_USER_OR_KERNEL` — This is required for the macro to function correctly. Please refer to Section B.8.12 for more details regarding the `COPY_TO_USER_OR_KERNEL` and `COPY_FROM_USER_OR_KERNEL` macros.

Example

```
void __cdecl KP_Call(PVOID pDrvContext,
   WD_KERNEL_PLUGIN_CALL *kpCall, BOOL fIsKernelMode)
{
    kpCall->dwResult = MY_DRV_OK;
    switch (kpCall->dwMessage)
    {
        /* In this sample we implement a GetVersion message */
        case MY_DRV_MSG_VERSION:
            {
              DWORD dwVer = 100;
              MY_DRV_VERSION *ver = (MY_DRV_VERSION *)kpCall->pData;
              COPY_TO_USER_OR_KERNEL(&ver->dwVer, &dwVer,
                  sizeof(DWORD), fIsKernelMode);
              COPY_TO_USER_OR_KERNEL(ver->cVer, "My Driver V1.00",
                  sizeof("My Driver V1.00")+1, fIsKernelMode);

              kpCall->dwResult = MY_DRV_OK;
            }
            break;
        /* You can implement other messages here */
        default:
            kpCall->dwResult = MY_DRV_NO_IMPL_MESSAGE;
    }
}
```

B.8.5. KP_Event

Purpose

Called when a Plug-and-Play or power management event for the device is received, provided the user-mode application first called `WDC_EventRegister()` [B.3.52] with `fUseKP = TRUE` (or the low-level `EventRegister()` function with a Kernel PlugIn handle — see **WinDriver PCI Low-Level API Reference**) (see the Remarks below).

Prototype

```
BOOL __cdecl KP_Event(
    PVOID pDrvContext,
    WD_EVENT *wd_event);
```

`KP_FUNC_EVENT` Kernel PlugIn callback function type.

Parameters

Name	Type	Input/Output
pDrvContext	PVOID	Input/Output
wd_event	WD_EVENT*	Input

Description

Name	Description
pDrvContext	Driver context data that was set by `KP_Open` [B.8.2] and will also be passed to `KP_Close` [B.8.3], `KP_IntEnable` [B.8.6] and `KP_Call` [B.8.4]
wd_event	Pointer to the PnP/power management event information received from the user mode

Return Value

`TRUE` in order to notify the user about the event.

Remarks

`KP_Event` will be called if the user mode process called `WDC_EventRegister()` [B.3.52] with `fUseKP= TRUE` (or of the low-level `EventRegister()` function was called with a Kernel PlugIn handle — see the **WinDriver PCI Low-Level API Reference**).

Example

```
BOOL __cdecl KP_Event(PVOID pDrvContext, WD_EVENT *wd_event)
{
    /* Handle the event here */
    return TRUE; /* Return TRUE to notify the user about the event */
}
```

B.8.6. KP_IntEnable

Purpose

Called when `WD_IntEnable`() (see **WinDriver PCI Low-Level API Reference**) is called from the user mode with a Kernel PlugIn handle.
`WD_IntEnable`() is called automatically from `WDC_IntEnable`() [B.3.48] and `InterruptEnable`() (see **WinDriver PCI Low-Level API Reference**).

The interrupt context that is set by this function (`*ppIntContext`) will be passed to the rest of the Kernel PlugIn interrupt functions.

Prototype

```
BOOL __cdecl KP_IntEnable (
    PVOID pDrvContext,
    WD_KERNEL_PLUGIN_CALL *kpCall,
    PVOID *ppIntContext);
```

`KP_FUNC_INT_ENABLE` Kernel PlugIn callback function type.

Parameters

Name	Type	Input/Output
pDrvContext	PVOID	Input/Output
kpCall	WD_KERNEL_PLUGIN_CALL	Input
• dwMessage	DWORD	Input
• pData	PVOID	Input/Output
• dwResult	DWORD	Output
ppIntContext	PVOID*	Input/Output

Description

Name	Description
pDrvContext	Driver context data that was set by `KP_Open` [B.8.2] and will also be passed to `KP_Close` [B.8.3], `KP_Call` [B.8.4] and `KP_Event` [B.8.5]
kpCall	Structure with information from `WD_IntEnable`() [B.9.3]
ppIntContext	Pointer to interrupt context data that will be passed to `KP_IntDisable` [B.8.7] and to the Kernel PlugIn interrupt handler functions. Use this context to keep interrupt specific information.

Return Value

Returns `TRUE` if enable is successful; otherwise returns `FALSE`.

Remarks

This function should contain any initialization needed for your Kernel PlugIn interrupt handling.

Example

```
BOOL __cdecl KP_IntEnable(PVOID pDrvContext,
     WD_KERNEL_PLUGIN_CALL *kpCall, PVOID *ppIntContext)
{
    DWORD *pIntCount;
    /* You can allocate specific memory for each interrupt
       in *ppIntContext */
    *ppIntContext = malloc(sizeof (DWORD));
    if (!*ppIntContext)
        return FALSE;
    /* In this sample the information is a DWORD used to
       count the incoming interrupts */
    pIntCount = (DWORD *) *ppIntContext;
    *pIntCount = 0; /* Reset the count to zero */
    return TRUE;
}
```

B.8.7. KP_IntDisable

Purpose

Called when `WD_IntDisable`() (see **WinDriver PCI Low-Level API Reference**) is called from the user mode for interrupts that were enabled in the Kernel PlugIn.
`WD_IntDisable`() is called automatically from `WDC_IntDisable`() [B.3.49] and `InterruptDisable`() (see **WinDriver PCI Low-Level API Reference**).

This function should free any memory that was allocated in `KP_IntEnable` [B.8.6].

Prototype

```
void __cdecl KP_IntDisable(PVOID pIntContext);
```

`KP_FUNC_INT_DISABLE` Kernel PlugIn callback function type.

Parameters

Name	Type	Input/Output
pIntContext	PVOID	Input

Description

Name	Description
pIntContext	Interrupt context data that was set by `KP_IntEnable` [B.8.6]

Return Value

None

Example

```
void __cdecl KP_IntDisable(PVOID pIntContext)
{
  /* You can free the interrupt specific memory
     allocated to pIntContext here */
  free(pIntContext);
}
```

B.8.8. KP_IntAtIrql

Purpose

High-priority legacy interrupt handler routine, which is run at high interrupt request level. This function is called upon the arrival of a legacy interrupt that has been enabled using a Kernel PlugIn driver — see the description of `WDC_IntEnable`() [B.3.48] or the low-level `InterruptEnable`() and `WD_IntEnable`() functions (see **WinDriver PCI Low-Level API Reference**).

Prototype

```
BOOL __cdecl KP_IntAtIrql(
    PVOID pIntContext,
    BOOL *pfIsMyInterrupt);
```

`KP_FUNC_INT_AT_IRQL` Kernel PlugIn callback function type.

Parameters

Name	Type	Input/Output
pIntContext	PVOID	Input/Output
pfIsMyInterrupt	BOOL*	Output

Description

Name	Description
pIntContext	Pointer to interrupt context data that was set by `KP_IntEnable` [B.8.6] and will also be passed to `KP_IntAtDpc` [B.8.9] (if executed) and `KP_IntDisable` [B.8.7]
pfIsMyInterrupt	Set `*pfIsMyInterrupt` to `TRUE` if the interrupt belongs to this driver; otherwise set it to `FALSE` in order to enable the interrupt service routines of other drivers for the same interrupt to be called

Return Value

`TRUE` if deferred interrupt processing (DPC) is required; otherwise `FALSE`.

Remarks

- Code running at IRQL will only be interrupted by higher priority interrupts.
- Code running at high IRQL is limited in the following ways:
  - It may only access non-pageable memory.
  - It may only call the following functions (or wrapper functions that call these functions):
    - `WDC_xxx`() read/write address or configuration space functions.
    - `WDC_MultiTransfer`() [B.3.30], or the low-level `WD_Transfer`(), `WD_MultiTransfer`(), or `WD_DebugAdd`() functions (see the **WinDriver PCI Low-Level API Reference**).
    - Specific kernel OS functions (such as WDK functions) that can be called from high interrupt request level. Note that the use of such functions may break the code's portability to other operating systems.
  - It may **not** call `malloc`(), `free`(), or any `WDC_xxx` or `WD_xxx` API other than those listed above.
- The code performed at high interrupt request level should be minimal (e.g., only the code that acknowledges level-sensitive interrupts), since it is operating at a high priority. The rest of your code should be written in `KP_IntAtDpc` [B.8.9], which runs at the deferred DISPATCH level and is not subject to the above restrictions.

Example

```
BOOL __cdecl KP_IntAtIrql(PVOID pIntContext,
    BOOL *pfIsMyInterrupt)
{
    DWORD *pdwIntCount = (DWORD*)pIntContext;

    /* Check your hardware here to see if the interrupt belongs to you.
       If it does, you must set *pfIsMyInterrupt to TRUE.
       Otherwise, set *pfIsMyInterrupt to FALSE. */
    *pfIsMyInterrupt = FALSE;

    /* In this example we will schedule a DPC once in every 5 interrupts */
    (*pdwIntCount) ++;
    if (*pdwIntCount==5)
    {
        *pdwIntCount = 0;
        return TRUE;
    }

    return FALSE;
}
```

B.8.9. KP_IntAtDpc

Purpose

Deferred processing legacy interrupt handler routine.
This function is called once the high-priority legacy interrupt handling is completed, provided that `KP_IntAtIrql` [B.8.8] returned `TRUE`.

Prototype

```
DWORD __cdecl KP_IntAtDpc(
    PVOID pIntContext,
    DWORD dwCount);
```

`KP_FUNC_INT_AT_DPC` Kernel PlugIn callback function type.

Parameters

Name	Type	Input/Output
pIntContext	PVOID	Input/Output
dwCount	DWORD	Input

Description

Name	Description
pIntContext	Interrupt context data that was set by `KP_IntEnable` [B.8.6], passed to `KP_IntAtIrql` [B.8.8], and will be passed to `KP_IntDisable` [B.8.7]
dwCount	The number of times `KP_IntAtIrql` [B.8.8] returned `TRUE` since the last DPC call. If `dwCount` is 1, `KP_IntAtIrql` requested a DPC only once since the last DPC call. If the value is greater than 1, `KP_IntAtIrql` has already requested a DPC a few times, but the interval was too short, therefore `KP_IntAtDpc` was not called for each DPC request.

Return Value

Returns the number of times to notify user mode (i.e., return from `WD_IntWait`() — see the **WinDriver PCI Low-Level API Reference**).

Remarks

- Most of the interrupt handling should be implemented within this function, as opposed to the high-priority `KP_IntAtIrql` [B.8.8] interrupt handler.

- If `KP_IntAtDpc` returns with a value greater than zero, `WD_IntWait`() returns and the user-mode interrupt handler will be called in the amount of times set in the return value of `KP_IntAtDpc`. If you do not want the user-mode interrupt handler to execute, `KP_IntAtDpc` should return zero.

Example

```
DWORD __cdecl KP_IntAtDpc(PVOID pIntContext, DWORD dwCount)
{
  /* Return WD_IntWait as many times as KP_IntAtIrql
     scheduled KP_IntAtDpc */
  return dwCount;
}
```

B.8.10. KP_IntAtIrqlMSI

Purpose

High-priority Message-Signaled Interrupts (MSI) / Extended Message-Signaled Interrupts (MSI-X) handler routine, which is run at high interrupt request level. This function is called upon the arrival of an MSI/MSI-X that has been enabled using a Kernel PlugIn — see the description of `WDC_IntEnable`() [B.3.48] or the low-level `InterruptEnable`() and `WD_IntEnable`() functions (see **WinDriver PCI Low-Level API Reference**).

Prototype

```
BOOL __cdecl KP_PCI_IntAtIrqlMSI(
    PVOID pIntContext,
    ULONG dwLastMessage,
    DWORD dwReserved);
```

`KP_FUNC_INT_AT_IRQL_MSI` Kernel PlugIn callback function type.

Parameters

Name	Type	Input/Output
pIntContext	PVOID	Input/Output
dwLastMessage	DWORD	Input
dwReserved	DWORD	Input

Description

Name	Description
pIntContext	Pointer to interrupt context data that was set by `KP_IntEnable` [B.8.6] and will also be passed to `KP_IntAtDpcMSI` [B.8.11] (if executed) and `KP_IntDisable` [B.8.7]
dwLastMessage	The message data for the last received interrupt (applicable only on Windows 7 and higher)
dwReserved	Reserved for future use. Do not use this parameter.

Return Value

`TRUE` if deferred MSI/MSI-X processing (DPC) is required; otherwise `FALSE`.

Remarks

- Code running at IRQL will only be interrupted by higher priority interrupts.
- Code running at high IRQL is limited in the following ways:
  - It may only access non-pageable memory.
  - It may only call the following functions (or wrapper functions that call these functions):
    - `WDC_xxx`() read/write address or configuration space functions.
    - `WDC_MultiTransfer`() [B.3.30], or the low-level `WD_Transfer`(), `WD_MultiTransfer`(), or `WD_DebugAdd`() functions (see the **WinDriver PCI Low-Level API Reference**).
    - Specific kernel OS functions (such as WDK functions) that can be called from high interrupt request level. Note that the use of such functions may break the code's portability to other operating systems.
  - It may **not** call `malloc`(), `free`(), or any `WDC_xxx` or `WD_xxx` API other than those listed above.
- The code performed at high interrupt request level should be minimal, since it is operating at a high priority. The rest of your code should be written in `KP_IntAtDpcMSI` [B.8.11], which runs at the deferred DISPATCH level and is not subject to the above restrictions.

Example

```
BOOL __cdecl KP_PCI_IntAtIrqlMSI(PVOID pIntContext,
    ULONG dwLastMessage, DWORD dwReserved)
{
    return TRUE;
}
```

B.8.11. KP_IntAtDpcMSI

Purpose

Deferred processing Message-Signaled Interrupts (MSI) / Extended Message-Signaled Interrupts (MSI-X) handler routine.
This function is called once the high-priority MSI/MSI-X handling is completed, provided that `KP_IntAtIrqlMSI` [B.8.10] returned `TRUE`.

Prototype

```
DWORD __cdecl KP_IntAtDpcMSI(
  PVOID pIntContext,
  DWORD dwCount,
  ULONG dwLastMessage,
  DWORD dwReserved);
```

`KP_FUNC_INT_AT_DPC_MSI` Kernel PlugIn callback function type.

Parameters

Name	Type	Input/Output
pIntContext	PVOID	Input/Output
dwCount	DWORD	Input
dwLastMessage	DWORD	Input
dwReserved	DWORD	Input

Description

Name	Description
pIntContext	Interrupt context data that was set by `KP_IntEnable` [B.8.6], passed to `KP_IntAtIrqlMSI` [B.8.10], and will be passed to `KP_IntDisable` [B.8.7]
dwCount	The number of times `KP_IntAtIrqlMSI` [B.8.10] returned `TRUE` since the last DPC call. If `dwCount` is 1, `KP_IntAtIrqlMSI` requested a DPC only once since the last DPC call. If the value is greater than 1, `KP_IntAtIrqlMSI` has already requested a DPC a few times, but the interval was too short, therefore `KP_IntAtDpcMSI` was not called for each DPC request.
dwLastMessage	The message data for the last received interrupt (applicable only on Windows 7 and higher)
dwReserved	Reserved for future use. Do not use this parameter.

Return Value

Returns the number of times to notify user mode (i.e., return from `WD_IntWait`() — see the **WinDriver PCI Low-Level API Reference**).

Remarks

- Most of the MSI/MSI-X handling should be implemented within this function, as opposed to the high-priority `KP_IntAtIrqlMSI` [B.8.10] interrupt handler.
- If `KP_IntAtDpcMSI` returns with a value greater than zero, `WD_IntWait`() returns and the user-mode interrupt handler will be called in the amount of times set in the return value of `KP_IntAtDpcMSI`. If you do not want the user-mode interrupt handler to execute, `KP_IntAtDpcMSI` should return zero.

Example

```
DWORD __cdecl KP_IntAtDpcMSI(PVOID pIntContext, DWORD dwCount,
  ULONG dwLastMessage, DWORD dwReserved)
{
  /* Return WD_IntWait as many times as KP_IntAtIrqlMSI
     scheduled KP_IntAtDpcMSI */
  return dwCount;
}
```

B.8.12. COPY_TO_USER_OR_KERNEL, COPY_FROM_USER_OR_KERNEL

Purpose

Macros for copying data from the user mode to the Kernel PlugIn and vice versa.

Remarks

- The `COPY_TO_USER_OR_KERNEL` and `COPY_FROM_USER_OR_KERNEL` are macros used for copying data (when necessary) to/from user-mode memory addresses (respectively), when accessing such addresses from within the Kernel PlugIn. Copying the data ensures that the user-mode address can be used correctly, even if the context of the user-mode process changes in the midst of the I/O operation. This is particularly relevant for long operations, during which the context of the user-mode process may change. The use of macros to perform the copy provides a generic solution for all supported operating systems.

- Note that if you wish to access the user-mode data from within the Kernel PlugIn interrupt handler functions, you should first copy the data into some variable in the Kernel PlugIn before the execution of the kernel-mode interrupt handler routines.

- The `COPY_TO_USER_OR_KERNEL` and `COPY_FROM_USER_OR_KERNEL` macros are defined in the **WinDriver\include\kpstdlib.h** header file.

- For an example of using the `COPY_TO_USER_OR_KERNEL` macro, see the `KP_Call` [B.8.4] implementation (`KP_PCI_Call`()) in the sample **WinDriver/samples/pci_diag/kp_pci/kp_pci.c** Kernel PlugIn file.

- To safely share a data buffer between the user-mode and Kernel PlugIn routines (e.g., `KP_IntAtIrql` [B.8.8] and `KP_IntAtDpc` [B.8.9]), consider using the technique outlined in the technical document titled "How do I share a memory buffer between Kernel PlugIn and user-mode projects for DMA or other purposes?" found under the "Kernel PlugIn" technical documents section of the "Support" section.

B.8.13. Kernel PlugIn Synchronization APIs

This section describes the Kernel Plug-In synchronization APIs.
These APIs support the following synchronization mechanisms:

- Spinlocks [B.8.13.2–B.8.13.5], which are used to synchronize between threads on a single or multiple CPU system.

The Kernel PlugIn spinlock functions can be called from any context apart from high interrupt request level. Hence, they can be called from any Kernel PlugIn function **except** for `KP_IntAtIrql` [B.8.8] and `KP_IntAtIrqlMSI` [B.8.10].
Note that the spinlock functions **can** be called from the deferred processing interrupt handler functions — `KP_IntAtDpc` [B.8.9] and `KP_IntAtDpcMSI` [B.8.11].

- Interlocked operations [B.8.13.6–B.8.13.7], which are used for synchronizing access to a variable that is shared by multiple threads by performing complex operations on the variable in an atomic manner.

The Kernel PlugIn interlocked functions can be called from any context in the Kernel PlugIn, including from high interrupt request level. Hence, they can be called from any Kernel PlugIn function, **including** the Kernel PlugIn interrupt handler functions.

B.8.13.1. Kernel PlugIn Synchronization Types

The Kernel PlugIn synchronization APIs use the following types:

- **`KP_SPINLOCK`** — A Kernel PlugIn spinlock object structure:

```
typedef struct _KP_SPINLOCK KP_SPINLOCK;
```

  `_KP_SPINLOCK` is an internal WinDriver spinlock object structure, opaque to the user.

- **`KP_INTERLOCKED`** — a Kernel PlugIn interlocked operations counter:

```
typedef volatile int KP_INTERLOCKED;
```

B.8.13.2. kp_spinlock_init()

Purpose

Initializes a new Kernel PlugIn spinlock object.

Prototype

```
KP_SPINLOCK * kp_spinlock_init(void);
```

Return Value

If successful, returns a pointer to the new Kernel PlugIn spinlock object [B.8.13.1], otherwise returns `NULL`.

B.8.13.3. kp_spinlock_wait()

Purpose

Waits on a Kernel PlugIn spinlock object.

Prototype

```
void kp_spinlock_wait(KP_SPINLOCK *spinlock);
```

Parameters

Name	Type	Input/Output
spinlock	KP_SPINLOCK*	Input

Description

Name	Description
spinlock	Pointer to the Kernel PlugIn spinlock object [B.8.13.1] on which to wait

Return Value

None

B.8.13.4. kp_spinlock_release()

Purpose

Releases a Kernel PlugIn spinlock object.

Prototype

```
void kp_spinlock_release(KP_SPINLOCK *spinlock);
```

Parameters

Name	Type	Input/Output
spinlock	KP_SPINLOCK*	Input

Description

Name	Description
spinlock	Pointer to the Kernel PlugIn spinlock object [B.8.13.1] to release

Return Value

None

B.8.13.5. kp_spinlock_uninit()

Purpose

Uninitializes a Kernel PlugIn spinlock object.

Prototype

```
void kp_spinlock_uninit(KP_SPINLOCK *spinlock);
```

Parameters

Name	Type	Input/Output
spinlock	KP_SPINLOCK*	Input

Description

Name	Description
spinlock	Pointer to the Kernel PlugIn spinlock object [B.8.13.1] to uninitialize

Return Value

None

B.8.13.6. kp_interlocked_init()

Purpose

Initializes a Kernel PlugIn interlocked counter.

Prototype

```
void kp_interlocked_init(KP_INTERLOCKED *target);
```

Parameters

Name	Type	Input/Output
target	KP_INTERLOCKED*	Input/Output

Description

Name	Description
target	Pointer to the Kernel PlugIn interlocked counter [B.8.13.1] to initialize

Return Value

None

B.8.13.7. kp_interlocked_uninit()

Purpose

Uninitializes a Kernel PlugIn interlocked counter.

Prototype

```
void kp_interlocked_uninit(KP_INTERLOCKED *target);
```

Parameters

Name	Type	Input/Output
target	KP_INTERLOCKED*	Input/Output

Description

Name	Description
target	Pointer to the Kernel PlugIn interlocked counter [B.8.13.1] to uninitialize

Return Value

None

B.8.13.8. kp_interlocked_increment()

Purpose

Increments the value of a Kernel PlugIn interlocked counter by one.

Prototype

```
int kp_interlocked_increment(KP_INTERLOCKED *target);
```

Parameters

Name	Type	Input/Output
target	KP_INTERLOCKED*	Input/Output

Description

Name	Description
target	Pointer to the Kernel PlugIn interlocked counter [B.8.13.1] to increment

Return Value

Returns the new value of the interlocked counter (`target`).

B.8.13.9. kp_interlocked_decrement()

Purpose

Decrements the value of a Kernel PlugIn interlocked counter by one.

Prototype

```
int kp_interlocked_decrement(KP_INTERLOCKED *target);
```

Parameters

Name	Type	Input/Output
target	KP_INTERLOCKED*	Input/Output

Description

Name	Description
target	Pointer to the Kernel PlugIn interlocked counter [B.8.13.1] to decrement

Return Value

Returns the new value of the interlocked counter (`target`).

B.8.13.10. kp_interlocked_add()

Purpose

Adds a specified value to the current value of a Kernel PlugIn interlocked counter.

Prototype

```
int kp_interlocked_add(
    KP_INTERLOCKED *target,
    int val);
```

Parameters

Name	Type	Input/Output
target	KP_INTERLOCKED*	Input/Output
val	val	Input

Description

Name	Description
target	Pointer to the Kernel PlugIn interlocked counter [B.8.13.1] to which to add
val	The value to add to the interlocked counter (`target`)

Return Value

Returns the new value of the interlocked counter (`target`).

B.8.13.11. kp_interlocked_read()

Purpose

Reads to the value of a Kernel PlugIn interlocked counter.

Prototype

```
int kp_interlocked_read(KP_INTERLOCKED *target);
```

Parameters

Name	Type	Input/Output
target	KP_INTERLOCKED*	Input

Description

Name	Description
target	Pointer to the Kernel PlugIn interlocked counter [B.8.13.1] to read

Return Value

Returns the value of the interlocked counter (`target`).

B.8.13.12. kp_interlocked_set()

Purpose

Sets the value of a Kernel PlugIn interlocked counter to the specified value.

Prototype

```
void kp_interlocked_set(
    KP_INTERLOCKED *target,
    int val);
```

Parameters

Name	Type	Input/Output
target	KP_INTERLOCKED*	Input/Output
val	val	Input

Description

Name	Description
target	Pointer to the Kernel PlugIn interlocked counter [B.8.13.1] to set
val	The value to set for the interlocked counter (`target`)

Return Value

None

B.8.13.13. kp_interlocked_exchange()

Purpose

Sets the value of a Kernel PlugIn interlocked counter to the specified value and returns the previous value of the counter.

Prototype

```
int kp_interlocked_exchange(
    KP_INTERLOCKED *target,
    int val);
```

Parameters

Name	Type	Input/Output
target	KP_INTERLOCKED*	Input/Output
val	val	Input

Description

Name	Description
target	Pointer to the Kernel PlugIn interlocked counter [B.8.13.1] to exchange
val	The new value to set for the interlocked counter (`target`)

Return Value

Returns the previous value of the interlocked counter (`target`).

B.9. Kernel PlugIn Structure Reference

This section contains detailed information about the different Kernel PlugIn related structures. **`WD_XXX`** structures are used in user-mode functions and **`KP_XXX`** structures are used in kernel-mode functions.

The Kernel PlugIn synchronization types are documented in Section B.8.13.1.

B.9.1. WD_KERNEL_PLUGIN

Defines a Kernel PlugIn open command.

This structure is used by the low-level `WD_KernelPlugInOpen`() and `WD_KernelPlugInClose`() functions — see the **WinDriver PCI Low-Level API Reference**.

Field	Type	Description
hKernelPlugIn	DWORD	Handle to a Kernel PlugIn
pcDriverName	PCHAR	Name of Kernel PlugIn driver. The name should be no longer than 12 characters and should not include the ***.sys** extension.
pcDriverPath	PCHAR	This field should be set to NULL. WinDriver will search for the driver in the operating system's drivers/modules directory.
pOpenData	PVOID	Data to pass to the `KP_Open` [B.8.2] callback in the Kernel PlugIn.

B.9.2. WD_INTERRUPT

Interrupt information structure.

This structure is used by the low-level `InterruptEnable`(), `InterruptDisable`(), `WD_IntEnable`(), `WD_IntDisable`(), `WD_IntWait`() and `WD_IntCount`() functions. `WDC_IntEnable`() [B.3.48] calls `InterruptEnable`(), which in turn calls `WD_IntEnable`(), `WD_IntWait`() and `WD_IntCount`(). `WDC_IntDisable`() [B.3.49] calls `InterruptDisable`(), which calls `WD_IntDisable`().

Field	Type	Description
kpCall	WD_KERNEL_ PLUGIN_CALL	Kernel PlugIn message information structure [B.9.3]. This structure contains the handle to the Kernel PlugIn and additional information that should be passed to the kernel-mode interrupt handler. If the Kernel PlugIn handle is zero, the interrupt is installed without a Kernel PlugIn interrupt handler. If a valid Kernel PlugIn handle is set, this structure will passed as a parameter to the `KP_IntEnable` [B.8.6] Kernel PlugIn callback function.

For information about the other members of `WD_INTERRUPT`, see the description of `InterruptEnable`() in the **WinDriver PCI Low-Level API Reference**.

B.9.3. WD_KERNEL_PLUGIN_CALL

Kernel PlugIn message information structure. This structure contains information that will be passed between a user-mode process and the Kernel PlugIn. The structure is used when passing messages to the Kernel PlugIn or when installing a Kernel PlugIn interrupt.

This structure is passed as a parameter to the Kernel PlugIn `KP_Call` [B.8.4] and `KP_IntEnable` [B.8.6] callback functions and is used by the low-level `WD_KernelPlugInCall`(), `InterruptEnable`() and `WD_IntEnable`() functions. `WD_KernelPlugInCall`() is called from the high-level `WDC_CallKerPlug`() function [B.3.23]. `InterruptEnable`() (which calls `WD_IntEnable`()) is called from the high-level `WDC_IntEnable`() function [B.3.48].

Field	Type	Description
hKernelPlugIn	DWORD	Handle to a Kernel PlugIn, returned by `WD_KernelPlugInOpen`() (see the **WinDriver PCI Low-Level API Reference**) — which is called from `WDC_KernelPlugInOpen`() [B.3.22], and from the `WDC_xxxDeviceOpen`() functions (PCI [B.3.17] / ISA [B.3.18]) when called with the name of a Kernel PlugIn driver [12.5]
dwMessage	DWORD	Message ID to pass to the Kernel PlugIn
pData	PVOID	Pointer to data to pass to the Kernel PlugIn
dwResult	DWORD	Value set by the Kernel PlugIn, to return back to user mode

B.9.4. KP_INIT

This structure is used by the Kernel PlugIn `KP_Init` function [B.8.1]. Its primary use is to notify WinDriver of the given driver's name and of which kernel-mode function to call when `WD_KernelPlugInOpen`() (see **WinDriver PCI Low-Level API Reference**) is called from the user mode.

`WD_KernelPlugInOpen`() is called from the high-level `WDC_KernelPlugInOpen`() [B.3.22] function.
It is also called from the `WDC_xxxDeviceOpen`() functions (PCI [B.3.17] / ISA [B.3.18]) when these functions are called with a valid Kernel PlugIn driver (set in the `pcKPDriverName` parameter). However, to ensure the correct execution of your code in all scenarios — including execution of a 32-bit application with a 64-bit Kernel PlugIn driver — do not use the device-open functions to open a handle to the Kernel PlugIn driver.

Field	Type	Description
dwVerWD	DWORD	The version of the WinDriver Kernel PlugIn library.
cDriverName	CHAR[12]	The device driver name, up to 12 characters.
funcOpen	KP_FUNC_OPEN	Standard `KP_Open` callback function [B.8.2], which will be called when a user-mode application opens a handle to a Kernel PlugIn driver [12.5], except when opening a handle to a 64-bit driver from a 32-bit application (in which case **`funcOpen_32_64`** will be used).
funcOpen_32_64	KP_FUNC_OPEN	`KP_Open` callback function [B.8.2] that will be called when a 32-bit application opens a handle to a 64-bit Kernel PlugIn driver [12.5], except for a 32-bit application request to open a handle to a 64-bit driver (when **`funcOpen_32_64`** will be used) [B.8.2].

B.9.5. KP_OPEN_CALL

This is the structure through which the Kernel PlugIn defines the names of its callback functions (other than `KP_Open`). It is used from the `KP_Open` [B.8.2] Kernel PlugIn function, which sets the callbacks in the structure.

A Kernel PlugIn may implement the following callback functions (other than `KP_Open` [B.8.2]):

- **funcClose** — Called when the user-mode process is done with this instance of the driver.

- **funcCall** — Called when the user mode process calls `WDC_CallKerPlug`() [B.3.23], or the low-level `WD_KernelPlugInCall`() function (see the **WinDriver PCI Low-Level API Reference**), which is called from `WDC_CallKerPlug`().
  This is a general-purpose function. You can use it to implement any functionality that should run in kernel mode (except the interrupt handler, which is a special case). The `funcCall` callback determines which function to execute according to the message passed to it from the user mode.

- **funcIntEnable** — Called when the user-mode process calls `WD_IntEnable`() with a Kernel PlugIn handle. `WD_IntEnable`() is called from `InterruptEnable`() (see **WinDriver PCI Low-Level API Reference**), which is called from the high-level `WDC_IntEnable`() function [B.3.48]. When calling `WDC_IntEnable`() with `fUseKP = TRUE`, the function calls `InterruptEnable`() with a Kernel PlugIn handle.
  This callback function should perform any initialization required when enabling an interrupt.

- **funcIntDisable** — Interrupt cleanup function, which is called when the user-mode process calls `WD_IntDisable`() — called from `InterruptDisable`() (see **WinDriver PCI Low-Level API Reference**), which is called from `WDC_IntDisable`() [B.3.49] — after having enabled interrupts using a Kernel PlugIn driver.

- **funcIntAtIrql** — High-priority kernel-mode legacy interrupt handler. This callback function is called at high interrupt request level when WinDriver processes a legacy interrupt that is assigned to this Kernel PlugIn. If this function returns a value greater than zero, the `funcIntAtDpc`() callback is called as a Deferred Procedure Call (DPC).

- **funcIntAtDpc** — Most of your legacy interrupt handler code should be written in this callback. It is called as a Deferred Procedure Call (DPC) if `funcIntAtIrql`() returned a value greater than zero.

- **funcIntAtIrqlMSI** — High-priority kernel-mode PCI Message-Signaled Interrupts (MSI) and Extended Message-Signaled Interrupts (MSI-X) handler. This callback function is called at high interrupt request level when WinDriver processes an MSI/MSI-X that is assigned to this Kernel PlugIn. If this function returns a value greater than zero, the `funcIntAtDpcMSI`() callback is called as a Deferred Procedure Call (DPC).
  Note: MSI/MSI-X is supported on Linux and Windows 7 and higher.

- **funcIntAtDpcMSI** — Most of your PCI MSI/MSI-X handler code should be written in this callback. It is called as a Deferred Procedure Call (DPC) if `funcIntAtIrqlMSI`() returned a value greater than zero.
  Note: MSI/MSI-X is supported on Linux and Windows 7 and higher.

- **funcEvent** — Called when a Plug-and-Play or power management event occurs, if the user-mode process first called `WDC_EventRegister`() [B.3.52] with `fUseKP = TRUE` (or if the low-level `EventRegister`() function was called with a Kernel PlugIn handle — see **WinDriver PCI Low-Level API Reference**). This callback function should implement the desired kernel handling for Plug-and-Play and power management events.

Field	Type	Description
funcClose	KP_FUNC_CLOSE	Name of your `KP_Close` [B.8.3] function in the kernel.
funcCall	KP_FUNC_CALL	Name of your `KP_Call` [B.8.4] function in the kernel.
funcIntEnable	KP_FUNC_INT_ENABLE	Name of your `KP_IntEnable` [B.8.6] function in the kernel.
funcIntDisable	KP_FUNC_INT_DISABLE	Name of your `KP_IntDisable` [B.8.7] function in the kernel.
funcIntAtIrql	KP_FUNC_INT_AT_IRQL	Name of your `KP_IntAtIrql` [B.8.8] function in the kernel.
funcIntAtDpc	KP_FUNC_INT_AT_DPC	Name of your `KP_IntAtDpc` [B.8.9] function in the kernel.
funcIntAtIrqlMSI	KP_FUNC_INT_AT_IRQL_MSI	Name of your `KP_IntAtIrqlMSI` [B.8.10] function in the kernel. Note: MSI/MSI-X is supported on Linux and Windows 7 and higher.
funcIntAtDpcMSI	KP_FUNC_INT_AT_DPC_MSI	Name of your `KP_IntAtDpcMSI` [B.8.11] function in the kernel. Note: MSI/MSI-X is supported on Linux and Windows 7 and higher.
funcEvent	KP_FUNC_EVENT	Name of your `KP_Event` [B.8.5] function in the kernel.

B.10. User-Mode Utility Functions

This section describes a number of user-mode utility functions you will find useful for implementing various tasks. These utility functions are multi-platform, implemented on all operating systems supported by WinDriver.

B.10.1. Stat2Str

Purpose

Retrieves the status string that corresponds to a status code.

Prototype

```
const char *Stat2Str(DWORD dwStatus);
```

Parameters

Name	Type	Input/Output
dwStatus	DWORD	Input

Description

Name	Description
• dwStatus	A numeric status code

Return Value

Returns the verbal status description (string) that corresponds to the specified numeric status code.

Remarks

See Section B.11 for a complete list of status codes and strings.

B.10.2. get_os_type

Purpose

Retrieves the type of the operating system.

Prototype

```
OS_TYPE get_os_type(void);
```

Return Value

Returns the type of the operating system.
If the operating system type is not detected, returns `OS_CAN_NOT_DETECT`.

B.10.3. check_secureBoot_enabled

Purpose

Checks whether the Secure Boot feature is enabled on the system. Developing drivers while Secure Boot is enabled can result in driver installation problems.

Prototype

```
DWORD check_secureBoot_enabled(void);
```

Return Value

`WD_STATUS_SUCCESS` (0) when Secure Boot is enabled. `WD_WINDRIVER_STATUS_ERROR` when Secure Boot is disabled. Any other status when Secure Boot is not supported.

B.10.4. ThreadStart

Purpose

Creates a thread.

Prototype

```
DWORD ThreadStart(
    HANDLE *phThread,
    HANDLER_FUNC pFunc,
    void *pData);
```

Parameters

Name	Type	Input/Output
phThread	HANDLE*	Output
pFunc	typedef void (*HANDLER_FUNC)(void *pData);	Input
pData	VOID*	Input

Description

Name	Description
phThread	Returns the handle to the created thread
pFunc	Starting address of the code that the new thread is to execute. (The handler's prototype — `HANDLER_FUNC` — is defined in **utils.h**.)
pData	Pointer to the data to be passed to the new thread

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.10.5. ThreadWait

Purpose

Waits for a thread to exit.

Prototype

```
void ThreadWait(HANDLE hThread);
```

Parameters

Name	Type	Input/Output
hThread	HANDLE	Input

Description

Name	Description
hThread	The handle to the thread whose completion is awaited

Return Value

None

B.10.6. OsEventCreate

Purpose

Creates an event object.

Prototype

```
DWORD OsEventCreate(HANDLE *phOsEvent);
```

Parameters

Name	Type	Input/Output
phOsEvent	HANDLE*	Output

Description

Name	Description
phOsEvent	The pointer to a variable that receives a handle to the newly created event object

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.10.7. OsEventClose

Purpose

Closes a handle to an event object.

Prototype

```
void OsEventClose(HANDLE hOsEvent);
```

Parameters

Name	Type	Input/Output
hOsEvent	HANDLE	Input

Description

Name	Description
hOsEvent	The handle to the event object to be closed

Return Value

None

B.10.8. OsEventWait

Purpose

Waits until a specified event object is in the signaled state or the time-out interval elapses.

Prototype

```
DWORD OsEventWait(
    HANDLE hOsEvent,
    DWORD dwSecTimeout);
```

Parameters

Name	Type	Input/Output
hOsEvent	HANDLE	Input
dwSecTimeout	DWORD	Input

Description

Name	Description
hOsEvent	The handle to the event object
dwSecTimeout	Time-out interval of the event, in seconds. For an infinite wait, set the timeout to `INFINITE`.

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.10.9. OsEventSignal

Purpose

Sets the specified event object to the signaled state.

Prototype

```
DWORD OsEventSignal(HANDLE hOsEvent);
```

Parameters

Name	Type	Input/Output
hOsEvent	HANDLE	Input

Description

Name	Description
hOsEvent	The handle to the event object

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.10.10. OsEventReset

Purpose

Resets the specified event object to the non-signaled state.

Prototype

```
DWORD OsEventReset(HANDLE hOsEvent);
```

Parameters

Name	Type	Input/Output
hOsEvent	HANDLE	Input

Description

Name	Description
hOsEvent	The handle to the event object

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.10.11. OsMutexCreate

Purpose

Creates a mutex object.

Prototype

```
DWORD OsMutexCreate(HANDLE *phOsMutex);
```

Parameters

Name	Type	Input/Output
phOsMutex	HANDLE*	Output

Description

Name	Description
phOsMutex	The pointer to a variable that receives a handle to the newly created mutex object

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.10.12. OsMutexClose

Purpose

Closes a handle to a mutex object.

Prototype

```
void OsMutexClose(HANDLE hOsMutex);
```

Parameters

Name	Type	Input/Output
hOsMutex	HANDLE	Input

Description

Name	Description
hOsMutex	The handle to the mutex object to be closed

Return Value

None

B.10.13. OsMutexLock

Purpose

Locks the specified mutex object.

Prototype

```
DWORD OsMutexLock(HANDLE hOsMutex);
```

Parameters

Name	Type	Input/Output
hOsMutex	HANDLE	Input

Description

Name	Description
hOsMutex	The handle to the mutex object to be locked

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.10.14. OsMutexUnlock

Purpose

Releases (unlocks) a locked mutex object.

Prototype

```
DWORD OsMutexUnlock(HANDLE hOsMutex);
```

Parameters

Name	Type	Input/Output
hOsMutex	HANDLE	Input

Description

Name	Description
hOsMutex	The handle to the mutex object to be unlocked

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.10.15. PrintDbgMessage

Purpose

Sends debug messages to the Debug Monitor.

Prototype

```
void PrintDbgMessage(
    DWORD dwLevel,
    DWORD dwSection,
    const char *format
    [, argument]...);
```

Parameters

Name	Type	Input/Output
dwLevel	DWORD	Input
dwSection	DWORD	Input
format	const char*	Input
argument		Input

Description

Name	Description
dwLevel	Assigns the level in the Debug Monitor, in which the data will be declared. If zero, `D_ERROR` will be declared. For more details please refer to `DEBUG_LEVEL` in **windrvr.h**.
dwSection	Assigns the section in the Debug Monitor, in which the data will be declared. If zero, `S_MISC` will be declared. For more details please refer to DEBUG_SECTION in **windrvr.h**.
format	Format-control string
argument	Optional arguments, limited to 256 bytes

Return Value

None

B.10.16. WD_LogStart

Purpose

Opens a log file.

Prototype

```
DWORD WD_LogStart(
    const char *sFileName,
    const char *sMode);
```

Parameters

Name	Type	Input/Output
sFileName	const char*	Input
sMode	const char*	Input

Description

Name	Description
sFileName	Name of log file to be opened
sMode	Type of access permitted. For example, NULL or **w** opens an empty file for writing, and if the given file exists, its contents are destroyed; **a** opens a file for writing at the end of the file (i.e., append).

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

Remarks

Once a log file is opened, all API calls are logged in this file.
You may add your own printouts to the log file by calling `WD_LogAdd`() [B.10.18].

B.10.17. WD_LogStop

Purpose

Closes a log file.

Prototype

```
VOID WD_LogStop(void);
```

Return Value

None

B.10.18. WD_LogAdd

Purpose

Adds user printouts into log file.

Prototype

```
VOID DLLCALLCONV WD_LogAdd(
    const char *sFormat
    [, argument ]...);
```

Parameters

Name	Type	Input/Output
sFormat	const char*	Input
argument		Input

Description

Name	Description
sFormat	Format-control string
argument	Optional format arguments

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

B.11. WinDriver Status Codes

B.11.1. Introduction

Most of the WinDriver functions return a status code, where zero (`WD_STATUS_SUCCESS`) means success and a non-zero value means failure.
The `Stat2Str`() functions can be used to retrieve the status description string for a given status code. The status codes and their descriptive strings are listed below.

B.11.2. Status Codes Returned by WinDriver

Status Code	Description
WD_STATUS_SUCCESS	Success
WD_STATUS_INVALID_WD_HANDLE	Invalid WinDriver handle
WD_WINDRIVER_STATUS_ERROR	Error
WD_INVALID_HANDLE	Invalid handle
WD_INVALID_PIPE_NUMBER	Invalid pipe number
WD_READ_WRITE_CONFLICT	Conflict between read and write operations
WD_ZERO_PACKET_SIZE	Packet size is zero
WD_INSUFFICIENT_RESOURCES	Insufficient resources
WD_UNKNOWN_PIPE_TYPE	Unknown pipe type
WD_SYSTEM_INTERNAL_ERROR	Internal system error
WD_DATA_MISMATCH	Data mismatch
WD_NO_LICENSE	No valid license
WD_NOT_IMPLEMENTED	Function not implemented
WD_KERPLUG_FAILURE	Kernel PlugIn failure
WD_FAILED_ENABLING_INTERRUPT	Failed enabling interrupt
WD_INTERRUPT_NOT_ENABLED	Interrupt not enabled
WD_RESOURCE_OVERLAP	Resource overlap
WD_DEVICE_NOT_FOUND	Device not found
WD_WRONG_UNIQUE_ID	Wrong unique ID
WD_OPERATION_ALREADY_DONE	Operation already done
WD_SET_CONFIGURATION_FAILED	Set configuration operation failed
WD_CANT_OBTAIN_PDO	Cannot obtain PDO
WD_TIME_OUT_EXPIRED	Timeout expired
WD_IRP_CANCELED	IRP operation canceled

Status Code	Description
WD_FAILED_USER_MAPPING	Failed to map in user space
WD_FAILED_KERNEL_MAPPING	Failed to map in kernel space
WD_NO_RESOURCES_ON_DEVICE	No resources on the device
WD_NO_EVENTS	No events
WD_INVALID_PARAMETER	Invalid parameter
WD_INCORRECT_VERSION	Incorrect WinDriver version installed
WD_TRY_AGAIN	Try again
WD_INVALID_IOCTL	Received an invalid IOCTL
WD_OPERATION_FAILED	Operation failed
WD_INVALID_32BIT_APP	Received an invalid 32-bit IOCTL
WD_TOO_MANY_HANDLES	No room to add handle
WD_NO_DEVICE_OBJECT	Driver not installed

Appendix C
WinDriver IPC

C.1. WinDriver IPC Overview

This section describes how to use WinDriver to perform Inter-Process Communication. WinDriver IPC allows several WinDriver-based user applications to send and receive user defined messages.

You should define a group ID that will be used by all your applications, and optionally you can also define several sub-group IDs to differentiate between different types of applications. For example, define one sub-group ID for operational applications, and another sub-group ID for monitoring or debug applications. This will enable you to send messages only to one type of application.

An IPC message can be sent in three ways:

- Multicast - The message will be sent to all processes that were registered with the same group ID.
- Sub-group Multicast - The message will be sent to all processes that were registered with the same sub-group ID.
- Unicast (By WinDriver IPC unique ID) - The message will be sent to one specific process.

In order to start working with WinDriver IPC each user application must first register by calling `WDS_IpcRegister`() [C.2.2]. It must provide a group ID and a sub-group ID and can optionally provides callback function to receive incoming messages.

WinDriver IPC unique ID is received either in the result of `WDS_IpcScanProcs`() [C.2.5] or in the message received by the callback function.

Multicast messages may be sent by calling `WDS_IpcMulticast`() [C.2.6] or `WDS_IpcSubGroupMulticast`() [C.2.7], while unicast messages may be sent by WinDriver IPC unique ID by calling `WDS_IpcUidUnicast`() [C.2.8].

Query of current registered processes can be done using `WDS_IpcScanProcs`() [C.2.5].

C.2. WinDriver IPC API Reference

This section describes the WinDriver IPC API defined in the **WinDriver/include/wds_lib.h** header file.

C.2.1. IPC_MSG_RX_HANDLER()

Purpose

WinDriver IPC message handler callback.

Prototype

```
typedef void (*IPC_MSG_RX_HANDLER)(
    WDS_IPC_MSG_RX *pIpcRxMsg,
    void *pData);
```

Parameters

Name	Type	Input/Output
pIpcRxMsg	WDS_IPC_MSG_RX *	Input
• dwSenderUID	DWORD	Input
• dwMsgID	DWORD	Input
• qwMsgData	UINT64	Input
pData	void *	Input

Description

Name	Description
pIpcRxMsg	Pointer to the received IPC message
• dwSenderUID	WinDriver IPC unique ID of the sending process
• dwMsgID	A 32 bit unique number defined by the user application. This number should be known to all user-applications that work under WinDriver IPC and share the same group ID
• qwMsgData	Optional - 64 bit additional data from the sending user-application process
pData	Application specific data opaque as passed to `WDS_IpcRegister()` [C.2.2]

C.2.2. WDS_IpcRegister()

Purpose

Registers an application with WinDriver IPC.

This API is not part of the standard WinDriver APIs, and is not included in the standard version of WinDriver. It is part of "WinDriver for Server" API and requires "WinDriver for Server" license. Note that "WinDriver for Server" APIs are included in WinDriver evaluation version.

Prototype

```
DWORD DLLCALLCONV WDS_IpcRegister(
    const CHAR *pcProcessName,
    DWORD dwGroupID,
    DWORD dwSubGroupID,
    DWORD dwAction,
    IPC_MSG_RX_HANDLER pFunc,
    void *pData);
```

Parameters

Name	Type	Input/Output
pcProcessName	const CHAR*	Input
dwGroupID	DWORD	Input
dwSubGroupID	DWORD	Input
dwAction	DWORD	Input
pFunc	see `IPC_MSG_RX_HANDLER()` [C.2.1]	Input
pData	void*	Input

Description

Name	Description
pcProcessName	Optional process name string
dwGroupID	A unique group ID represent the specific application. Must be a positive ID
dwSubGroupID	Sub-group ID that should identify your user application type in case you have several types that may work simultaneously. Must be a positive ID
dwAction	IPC message type to receive, which can consist one of the enumeration values listed below: • **`WD_IPC_UNICAST_MSG`**: • **`WD_IPC_MULTICAST_MSG`**: • **`WD_IPC_ALL_MSG`**:
pFunc	A user-mode IPC message handler callback function, which will be called when a message was received by WinDriver from a different process (see **`dwActions`**) occurs. (See `IPC_MSG_RX_HANDLER`() [C.2.1])
pData	Data for the user-mode IPC message handler callback routine (**`pFunc`**)

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

Remarks

- You should choose your user applications a unique group ID parameter. This is done as a precaution to prevent several applications that use WinDriver with its default driver name (windrvrXXXX) to get mixing messages. We strongly recommend that you rename your driver before distributing it to avoid this issue entirely, among other issue (See Section 15.2 on renaming you driver name).

- The sub-group id parameter should identify your user application type in case you have several types that may work simultaneously.

C.2.3. WDS_IpcUnRegister()

Purpose

This function enables the user application to unregister with WinDriver IPC.

This API is not part of the standard WinDriver APIs, and is not included in the standard version of WinDriver. It is part of "WinDriver for Server" API and requires "WinDriver for Server" license. Note that "WinDriver for Server" APIs are included in WinDriver evaluation version.

Prototype

```
DWORD DLLCALLCONV WDS_IpcUnRegister(void);
```

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

C.2.4. WDS_IsIpcRegistered()

Purpose

Enables the application to check if it is already registered with WinDriver IPC.

This API is not part of the standard WinDriver APIs, and is not included in the standard version of WinDriver. It is part of "WinDriver for Server" API and requires "WinDriver for Server" license. Note that "WinDriver for Server" APIs are included in WinDriver evaluation version.

Prototype

```
DWORD DLLCALLCONV WDS_IsIpcRegistered(void);
```

Return Value

Returns `TRUE` if successful; otherwise returns `FALSE`.

C.2.5. WDS_IpcScanProcs()

Purpose

Scans and returns information of all registered processes that share the application process groupID (as was given to `WDS_IpcRegister`() [C.2.2] or a specific groupID.

This API is not part of the standard WinDriver APIs, and is not included in the standard version of WinDriver. It is part of "WinDriver for Server" API and requires "WinDriver for Server" license. Note that "WinDriver for Server" APIs are included in WinDriver evaluation version.

Prototype

```
DWORD DLLCALLCONV WDS_IpcScanProcs(
    DWORD dwGroupID,
    WDS_IPC_SCAN_RESULT *ipcScanProcs);
```

Parameters

Name	Type	Input/Output
dwGroupID	DWORD	Input
ipcScanProcs	WDS_IPC_SCAN_RESULT*	Output
• dwNumProcs	DWORD	Output
• procInfo	WD_IPC_PROCESS[]	Output
* cProcessName	CHAR*	Output
* dwSubGroupID	DWORD	Output
* dwGroupID	DWORD	Output
* hIpc	DWORD	Output

Description

Name	Description
dwGroupID	0 - Scan processes that share the current process group ID. Other - Scan for all processes that registered with the specific group ID.
ipcScanProcs	
• dwNumProcs	Number of matching processes
• procInfo	An array of matching processes[]
* cProcessName	Matched process name
* dwSubGroupID	Unique identifier of the process sub-group
* dwGroupID	Unique identifier of the processes group for discarding unrelated processes
* hIpc	IPC handle as returned by the low-level `WD_IpcRegister()` function

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

C.2.6. WDS_IpcMulticast()

Purpose

Sends a message to all processes that were registered with the same group ID as the sending process. The message won't be sent to the sending process.

This API is not part of the standard WinDriver APIs, and is not included in the standard version of WinDriver. It is part of "WinDriver for Server" API and requires "WinDriver for Server" license. Note that "WinDriver for Server" APIs are included in WinDriver evaluation version.

Prototype

```
DWORD DLLCALLCONV WDS_IpcMulticast(
    DWORD dwMsgID,
    UINT64 qwMsgData);
```

Parameters

Name	Type	Input/Output
dwMsgID	DWORD	Input
qwMsgData	UINT64	Input

Description

Name	Description
dwMsgID	A 32 bit unique number defined by the user application. This number should be known to all user-applications that work under WinDriver IPC and share the same group ID
qwMsgData	Optional - 64 bit additional data from the sending user-application

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

C.2.7. WDS_IpcSubGroupMulticast()

Purpose

Sends a message to all processes that registered with the same sub-group ID

This API is not part of the standard WinDriver APIs, and is not included in the standard version of WinDriver. It is part of "WinDriver for Server" API and requires "WinDriver for Server" license. Note that "WinDriver for Server" APIs are included in WinDriver evaluation version.

Prototype

```
DWORD DLLCALLCONV WDS_IpcSubGroupMulticast(
    DWORD dwRecipientSubGroupID,
    DWORD dwMsgID,
    UINT64 qwMsgData);
```

Parameters

Name	Type	Input/Output
dwRecipientSubGroupID	DWORD	Input
dwMsgID	DWORD	Input
qwMsgData	UINT64	Input

Description

Name	Description
dwRecipientSubGroupID	Recipient sub-group ID that should identify your user application type in case you have several types that may work simultaneously.
dwMsgID	A 32 bit unique number defined by the user application. This number should be known to all user-applications that work under WinDriver IPC and share the same group ID
qwMsgData	Optional - 64 bit additional data from the sending user-application

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

C.2.8. WDS_IpcUidUnicast()

Purpose

Sends a message to a specific process with WinDriver IPC unique ID

This API is not part of the standard WinDriver APIs, and is not included in the standard version of WinDriver. It is part of "WinDriver for Server" API and requires "WinDriver for Server" license. Note that "WinDriver for Server" APIs are included in WinDriver evaluation version.

Prototype

```
DWORD DLLCALLCONV WDS_IpcUidUnicast(
    DWORD dwRecipientUID,
    DWORD dwMsgID,
    UINT64 qwMsgData);
```

Parameters

Name	Type	Input/Output
dwRecipientUID	DWORD	Input
dwMsgID	DWORD	Input
qwMsgData	UINT64	Input

Description

Name	Description
dwRecipientUID	WinDriver IPC unique ID that should identify one of your user application. The reciepient UID can be obtained from the result of `WDS_IpcScanProcs`() [C.2.5] or the sender ID as received in the callback registered in `WDS_IpcRegister`() [C.2.2]
dwMsgID	A 32 bit unique number defined by the user application. This number should be known to all user-applications that work under WinDriver IPC and share the same group ID
qwMsgData	Optional - 64 bit additional data from the sending user-application

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.11].

Appendix D
Troubleshooting and Support

Please refer to the online WinDriver support page — https://www.jungo.com/st/support/windriver/ — for additional resources for developers, including

- Technical documents
- FAQs
- Samples
- Quick start guides

Appendix E
Evaluation Version Limitations

E.1. Windows WinDriver Evaluation Limitations

- Each time WinDriver is activated, an *Unregistered* message appears.
- When using DriverWizard, a dialogue box with a message stating that an evaluation version is being run appears on every interaction with the hardware.
- DriverWizard [4]:
  - Each time DriverWizard is activated, an *Unregistered* message appears.
  - An evaluation message is displayed on every interaction with the hardware using DriverWizard.
- WinDriver will function for only 30 days after the original installation.

E.2. Linux WinDriver Evaluation Limitations

- Each time WinDriver is activated, an *Unregistered* message appears.
- DriverWizard [4]:
  - Each time DriverWizard is activated, an *Unregistered* message appears.
  - An evaluation message is displayed on every interaction with the hardware using DriverWizard.
- WinDriver's kernel module will work for no more than 60 minutes at a time. To continue working, the WinDriver kernel module must be reloaded (unload and load the module) using the following commands:

The following commands must be executed with root privileges.

To unload —

```
# /sbin/modprobe -r windrvr1281
```

To load —

```
# <path to wdreg> windrvr1281
```

wdreg is provided in the **WinDriver/util** directory.

Appendix F
Purchasing WinDriver

Visit the WinDriver order page on our web site — https://www.jungo.com/st/order_wd/ — to select your WinDriver product(s) and receive a quote. Then fill in the WinDriver order form — available for download from the order page — and send it to Jungo by email or fax (see details in the order form and in the online order page). If you have installed the evaluation version of WinDriver, you can also find the order form in the **WinDriver/docs** directory, or access it via **Start | WinDriver | Order Form** on Windows.

The WinDriver license string will be emailed to you immediately.
Your WinDriver package will be sent to you via courier or registered mail.

Feel free to contact us with any question you may have. For full contact information, visit our contact web page: https://www.jungo.com/st/company/contact-us/.

Appendix G
Distributing Your Driver — Legal Issues

WinDriver is licensed per-seat. The WinDriver license allows one developer on a single machine to develop a device driver for a single device (VID/DID (PCI) or VID/PID (USB)), and to freely distribute the created driver without royalties, as outlined in the license agreement in the **WinDriver/docs/wd_license.pdf** file.

Appendix H
Additional Documentation

Updated Manuals

The most updated WinDriver user manuals can be found on Jungo's site at https://www.jungo.com/st/support/windriver/.

Version History

If you wish to view WinDriver version history, refer to the WinDriver release notes, available online at https://www.jungo.com/st/support/windriver/wdver/. The release notes include a list of the new features, enhancements and fixes that have been added in each WinDriver version.

Technical Documents

For additional information, refer to the WinDriver Technical Documents database: https://www.jungo.com/st/support/tech_docs_indexes/main_index.html.
This database includes detailed descriptions of WinDriver's features, utilities and APIs and their correct usage, troubleshooting of common problems, useful tips and answers to frequently asked questions.