VisualDSP++® 5.0
Device Drivers and System Services Manual for Blackfin® Processors

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ANALOG DEVICES

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PREFACE

Thank you for purchasing Analog Devices, Inc. development software for Analog Devices embedded processors.

Purpose of This Manual

The *VisualDSP++ 5.0 Update 4 Device Drivers and System Services Manual for Blackfin Processors* contains information about the Analog Devices device driver model and system services library suite. Included are architectural descriptions of the device driver design and each system service component. Also included is a description of the API calls into each library.

Intended Audience

The primary audience for this manual is a programmer who is familiar with Analog Devices Blackfin® processors. This manual assumes the audience has a working knowledge of the appropriate processor architecture and instruction set. Programmers who are unfamiliar with Analog Devices processors can use this manual, but should supplement it with other texts, such as hardware reference and programming reference manuals, that describe their target architecture.

Manual Contents Description

This manual contains:

- Chapter 1, "Introduction"
  Provides an overview of system services and device drivers.
- Chapter 2, "Interrupt Manager"
  Describes the system interrupt controller (SIC) manager that supports the general-purpose interrupt events.
- Chapter 3, "Power Management Module"
  Describes the power management module that supports dynamic power management of Blackfin processors.
- Chapter 4, "External Bus Interface Unit Module"
  Describes the external bus interface unit (EBIU) module that enables the power management module to manage the SDRAM controller operation.
- Chapter 5, "Deferred Callback Manager"
  Describes the deferred callback manager that is used by the application developer to effectively execute function calls.
- Chapter 6, "DMA Manager"
  Describes direct memory access (DMA) manager API.
- Chapter 7, "Programmable Flag Service"
  Describes the programmable flag service that provides interface into the programmable flag subsystem of the Blackfin processor.
- Chapter 8, "Timer Service"
  Describes the timer service that provides interface into the core, watchdog, and general-purpose timers of the Blackfin processor.

- Chapter 9, "Port Control Service"
  Describes the port control manager service used to assign the programmable flag pins to various functions (on ADSP-BF534, ADSP-BF536, and ADSP-BF537 processors only).

- Chapter 10, "Device Driver Manager"
  Describes the device driver model used to control devices, both internal and external, to ADI processors.

- Chapter 11, "Real-Time Clock Service"
  Describes the real-time clock service within the system services library and how to use it to enable the features of the real-time clock on Blackfin processors.

- Chapter 12, "File System Service"
  Describes the file system service (FSS), which provides access to mass storage media from the Blackfin processor.

What's New in This Manual

This revision (3.2) of the *VisualDSP++ 5.0 Update 4 Device Drivers and System Services Manual for Blackfin Processors* contains the following changes/additions:

- Removed obsoleted commands and added new commands to Chapter 6, "DMA Manager".

- Added new sections "DMA Traffic Control" on page 6-31 and "Device Manager Public Data Types and Enumerations" on page 10-66.

- Added new commands to Chapter 12, "File System Service".

- Modifications and corrections based on errata reports against the previous revision (3.1) of the manual.

Technical or Customer Support

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- Visit the Embedded Processing and DSP products Web site at `http://www.analog.com/processors/technical_support`
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  `processor.europe@analog.com (Europe support)`
  `processor.china@analog.com (China support)`
- Phone questions to **1-800-ANALOGD**
- Contact your Analog Devices, Inc. local sales office or authorized distributor
- Send questions by mail to:

```
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One Technology Way
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```

Supported Processors

The name *Blackfin* refers to a family of 16-bit, embedded processors. VisualDSP++® currently supports the following Blackfin families:

ADSP-BF52x, ADSP-BF53x, ADSP-BF54x, and ADSP-BF56x

Product Information

Product information can be obtained from the Analog Devices Web site, VisualDSP++ online Help system, and a technical library CD.

Analog Devices Web Site

The Analog Devices Web site, www.analog.com, provides information about a broad range of products—analog integrated circuits, amplifiers, converters, and digital signal processors.

To access a complete technical library for each processor family, go to http://www.analog.com/processors/technical_library. The manuals selection opens a list of current manuals related to the product as well as a link to the previous revisions of the manuals. When locating your manual title, note a possible errata check mark next to the title that leads to the current correction report against the manual.

Also note, MyAnalog.com is a free feature of the Analog Devices Web site that allows customization of a Web page to display only the latest information about products you are interested in. You can choose to receive weekly e-mail notifications containing updates to the Web pages that meet your interests, including documentation errata against all manuals. MyAnalog.com provides access to books, application notes, data sheets, code examples, and more.

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VisualDSP++ Online Documentation

Online documentation comprises the VisualDSP++ Help system, software tools manuals, hardware tools manuals, processor manuals, Dinkum Abridged C++ library, and FLEXnet License Tools software documentation. You can search easily across the entire VisualDSP++ documentation set for any topic of interest.

For easy printing, supplementary Portable Documentation Format (`.pdf`) files for all manuals are provided on the VisualDSP++ installation CD.

Each documentation file type is described as follows.

File	Description
`.chm`	Help system files and manuals in Microsoft Help format
`.htm` or `.html`	Dinkum Abridged C++ library and FLEXnet License Tools software documentation. Viewing and printing the `.html` files requires a browser, such as Internet Explorer 6.0 (or higher).
`.pdf`	VisualDSP++ and processor manuals in (PDF) format. Viewing and printing the `.pdf` files requires a PDF reader, such as Adobe Acrobat Reader (4.0 or higher).

Technical Library CD

The technical library CD contains seminar materials, product highlights, a selection guide, and documentation files of processor manuals, VisualDSP++ software manuals, and hardware tools manuals for the following processor families: Blackfin, SHARC®, TigerSHARC®, ADSP-218x, and ADSP-219x.

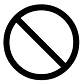
To order the technical library CD, go to `http://www.analog.com/processors/technical_library`, navigate to the manuals page for your processor, click the request CD check mark, and fill out the order form.

Data sheets, which can be downloaded from the Analog Devices Web site, change rapidly, and therefore are not included on the technical library CD. Technical manuals change periodically. Check the Web site for the latest manual revisions and associated documentation errata.

Notation Conventions

Text conventions used in this manual are identified and described as follows. Note that additional conventions, which apply only to specific chapters, may appear throughout this document.

Example	Description
`{this | that}`	Alternative required items in syntax descriptions appear within curly brackets and separated by vertical bars; read the example as `this` or `that`. One or the other is required.
`[this | that]`	Optional items in syntax descriptions appear within brackets and separated by vertical bars; read the example as an optional `this` or `that`.
`[this,…]`	Optional item lists in syntax descriptions appear within brackets delimited by commas and terminated with an ellipse; read the example as an optional comma-separated list of `this`.
`.SECTION`	Commands, directives, keywords, and feature names are in text with `letter gothic` font.
filename	Non-keyword placeholders appear in text with italic style format.
	Note: For correct operation, ... A Note provides supplementary information on a related topic. In the online version of this book, the word **Note** appears instead of this symbol.
	Caution: Incorrect device operation may result if ... **Caution:** Device damage may result if ... A Caution identifies conditions or inappropriate usage of the product that could lead to undesirable results or product damage. In the online version of this book, the word **Caution** appears instead of this symbol.

Example	Description
	**Warning:** Injury to device users may result if ... A Warning identifies conditions or inappropriate usage of the product that could lead to conditions that are potentially hazardous for devices users. In the online version of this book, the word **Warning** appears instead of this symbol.

1 INTRODUCTION

This manual describes the system services and device driver architecture for Analog Devices embedded processors.

The system services form a collection of functions that are commonly found in embedded systems. Each system service focuses on a specific set of functionality such as direct memory access (DMA), power management (PM), interrupt control (IC), and so on. Collectively, the system services provide a wealth of pre-built, optimized code that simplifies software development, allowing you to get Blackfin processor-based designs to market more quickly.

The device driver model provides a simple, clean and familiar interface into device drivers for Blackfin processors. The primary objective of the device driver model is to create a concise, effective, and easy-to-use interface through which applications can communicate with device drivers. Secondarily, the model and device manager software significantly simplifies the development of device drivers, making the development of new device drivers very straightforward.

Currently, the system services and device drivers are available for use with the following Blackfin families: ADSP-BF531/532/533, ADSP-BF534/536/537, ADSP-BF538/539, ADSP-BF542/544/547/548/549, ADSP-BF522/524/526, ADSP-BF532/525/527, and ADSP-BF561.

This chapter contains:

System Services Overview

The system services overview covers the following topics:

General

The current revision of the system services library consists of the following services:

- **Interrupt Control Service** – The interrupt control service allows the application to control and leverage the event and interrupt processing of the processor more effectively. Specific functionality allows the application to:
  - Set and detect the mappings of the interrupt priority levels to peripherals.
  - Use standard C functions as interrupt handlers.
  - Hook and unhook multiple interrupt handlers to the same interrupt priority level using both nesting and non-nesting capabilities.
  - Detect if a system interrupt is being asserted.
  - Protect and unprotect critical regions of code in a portable manner.
- **Power Management Service** – The power management service allows the application to control the dynamic power management capabilities of a Blackfin processor. Specific functionality allows the application to:
  - Set core and system clock operating frequencies with a function call.
  - Set and detect the internal voltage regulator settings.
  - Transition the processor among the various operating modes including, full-on, active, sleep, and so on.

- **External Bus Interface Unit Control Service (EBIU)** – The EBIU control service provides a collection of routines to set up the external interfaces of the Blackfin processor, including the SDRAM controller. This functionality enables you to:
  - Adjust SDRAM refresh and timing rates to optimal values for given system clock frequencies.
  - Set individual bus interface settings.
  - Complete single function setup for known configurations, such as the Blackfin EZ-KIT Lite platforms.
- **Deferred Callback Service** – The deferred callback service allows the application to be notified of asynchronous events outside of high-priority interrupt service routines. Using deferred callbacks typically improves the overall I/O capacity of the system while at the same time reducing interrupt latency. Specific functionality allows the application to:
  - Define how many callbacks can be pending at any point in time.
  - Define the interrupt priority level at which the callback service executes.
  - Create multiple callback services, each operating at a different interrupt priority level.
  - Post callbacks to a callback service with a relative priority among all other callbacks posted to the same callback service.
- **DMA Management Service** – The DMA management service provides access into the DMA controller of a Blackfin processor. The DMA management service allows the application to schedule

DMA operations, both peripheral and memory DMA, supporting both linear and two-dimensional transfer types. Specific functionality allows the application to:

- Set and detect the mapping of DMA channels to peripherals.
- Configure individual DMA channels for inbound/outbound traffic using circular (autobuffered) DMA or descriptor-based DMA.
- Command the DMA manager to issue live or deferred callbacks upon DMA completions.
- Queue descriptors, intermixing linear and two-dimensional transfers on DMA channels.
- Enable the DMA manager to loopback on descriptor chains automatically.
- Stream data continuously into or out of a memory stream or peripheral.
- Initiate linear and two-dimensional memory DMA transfers with simple C-like, `memcpy`-type functions.

- **Programmable Flag Service** – The programmable flag service provides a simple interface into the programmable flags, sometimes called general-purpose I/O, of the Blackfin processor. This allows the application to access and control the programmable flags through a clean and consistent interface. The programmable flag service allows the application to:

  - Configure the direction, either input or output, of any flag.
  - Set, clear, and toggle the value of all output flags.
  - Sense the value of input flags.
  - Install callbacks, including live and deferred callbacks when specific trigger conditions occur on a flag.

- **Timer Service** – The timer service provides applications, drivers, and a simple mechanism to control general-purpose, core, and watchdog timers of the Blackfin processor. The timer service allows the application to:
  - Configure and control any timer within the processor, including general-purpose, core, and watchdog timers.
  - Install callbacks, including both "live" and deferred callbacks, when timers expire or trigger.
- **Port Control Service** – (available only on the ADSP-BF534, ADSP-BF536, and ADSP-BF537 processors) The port control service configures the pin muxing hardware appropriately to ensure proper operation of the peripherals that share common input and output pins. All system services and device drivers automatically make the appropriate calls into the port control service to seamlessly configure the pin muxing hardware without any end-user or application interaction, other than initialization of the service.

- **Device Manager** – The device driver model is used to control devices, both internal and external to Analog Devices processors. Specific functionality allow the application to:
  - Open and close devices used by the application.
  - Configure and control devices.
  - Receive and transmit data through the devices using a variety of dataflow methods.

Application Interface

Each system service exports an application programming interface (API) that defines the interface into that service. Application software makes calls into the API of the system service to access the functionality that is to be controlled.

Each API can be called using the standard calling interface of the development toolset's C run-time model. The API of each service can be called by any C or assembly language program that adheres to the calling conventions and register usage of the C run-time model.

In addition to the application software using the API to make calls into a system service, some system services make calls into the API of other system services. For the most part, each service is independent of the other services; however, redundancies are eliminated by allowing one service to access the functionality of another service.

For example, does the application need to be notified when a DMA descriptor has completed processing, and the application has requested deferred callbacks? In this case, the DMA management service invokes the deferred callback service to effect the callback into the application.

Another example of combined operation between services involves the power management and EBIU services. Assume that the system has SDRAM and the application needs to conserve power by turning down the core and system clock frequencies. When the application calls the power management service to lower the operating frequencies, the power management service automatically invokes the EBIU service, which adjusts the SDRAM refresh rate to compensate for the reduced system clock frequency.

Figure 1-1 illustrates the current collection of system services and the API interactions among them.

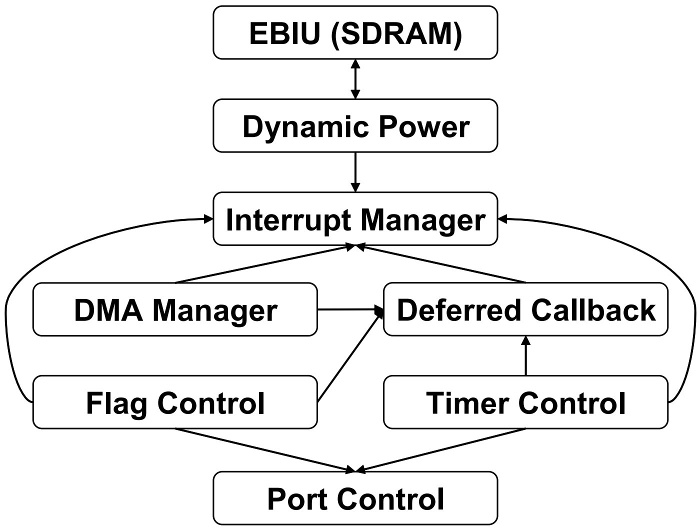


Figure 1-1. System Services and API Interactions

Dependencies

With few constraints, applications can use any individual service or combination of services within their application. Applications do not have to all the services. Further, each service does not need all the resources associated with the system that the service is controlling.

For example, the DMA manager does not need control over all DMA channels. The system can be configured for the DMA manager to control some channels, leaving the application or other software to control other DMA channels. (See the individual service chapters for more information on each service.) There are, however, dependencies within the services of which the application developer should be aware.

All current services, except the EBIU service, invoke the interrupt control service for the management of interrupt processing. The DMA manager, deferred callback, and power management services each depend on the interrupt control service to manage interrupt processing for them.

If directed by the application to adjust SDRAM timing automatically, the power management service uses the EBIU control service to affect SDRAM timing parameter changes when the power/operating speed profile of the processor is changed.

When configured to use deferred callbacks (as opposed to live or interrupt-time callbacks) the DMA manager leverages the capabilities of the deferred callback service to provide deferred callbacks to the application. However, when configured for live callbacks, the DMA manager does not use the deferred callback service.

The development toolset automatically determines these dependencies and links into the executable only those services that are required by the application. Because each service is built as its own object file within the system services library file, you can further reduce the code size of the final executable by commanding the linker to eliminate unused objects. Refer to the development toolset documentation for more information.

Initialization

Some system services rely on other system services; thus, there is a preferred initialization sequence. Usually it is preferable to initialize all services at one time, typically when the whole system is being initialized, rather than spreading out the initialization of various services at different times.

Most applications find the initialization sequence listed below to be optimal. Any service in the sequence that is not used by the application can simply be omitted from the sequence.

1. Interrupt control service
2. External bus interface unit
3. Power management service
4. Port control (ADSP-BF534/536/537 processors only)
5. Deferred callback service
6. DMA manager service
7. Programmable flag service
8. Timer service

Termination

Many embedded systems operate continuously in an endless loop and may never need to call the termination function of a service. Applications that do not have a need to terminate a service can save memory by never calling the termination function.

For applications that need to terminate services, as with the initialization sequence, there is a preferred sequence of terminating the services.

Most application find the termination sequence listed below to be optimal. Any service in the sequence that is not used by the application can simply be omitted from the sequence.

1. Timer service
2. Programmable flag service
3. DMA manager service
4. Deferred callback service
5. Port control (ADSP-BF534/536/537 processors only)
6. Power management service
7. External bus interface unit
8. Interrupt control service

System Services Directory and File Structure

All files for the system services are contained within the `Blackfin` directory tree. In VisualDSP++ installations, this directory is used for core development tools. Other development toolsets may use other directory names for their toolkits, but the system services can always be found within the `Blackfin` directory tree.

To use the system services, applications need only include a single include file in their source code, and link with a single system services library module that is appropriate for their configuration.

Accessing the System Services API

Applications using system services should include the `Blackfin/include/services` directory in the (compiler and/or assembler) preprocessor search path. User source files that access any of the system services APIs should simply include the `services.h` file, located in the `Blackfin/include/services` directory. User files do not need to include any other files to use the system services API.

The system services API and functionality are uniform and consistent across all Blackfin processors, including all single- and multi-core devices. Application software does not have to change, regardless of the Blackfin processor is being targeted. For example, application software running on a single-core ADSP-BF533 processor can operate unchanged on a multi-core ADSP-BF561 processor.

In order to provide this consistent API to the application, the system services API must be aware of the specific processor variant being targeted. You must ensure that the processor definition macro for the processor variant being targeted is defined when including the `services.h` include file.

The VisualDSP++ toolset automatically sets the processor definition macro when building projects. Application developers using the VisualDSP++ toolset need do nothing further to ensure the processor definition macro is defined.

Application developers using other toolsets, however, should ensure the processor definition macro is appropriately defined. The `services.h` file enumerates the specific processor variants that are supported. These processor variants include:

`__ADSPBF531__`	The ADSP-BF531 processor
`__ADSPBF532__`	The ADSP-BF532 processor
`__ADSPBF533__`	The ADSP-BF533 processor
`__ADSPBF534__`	The ADSP-BF534 processor
`__ADSPBF535__`	The ADSP-BF535 processor
`__ADSPBF536__`	The ADSP-BF536 processor
`__ADSPBF537__`	The ADSP-BF537 processor

`__ADSPBF538__`	The ADSP-BF538 processor
`__ADSPBF539__`	The ADSP-BF539 processor
`__ADSPBF561__`	The ADSP-BF561 processor

The `services.h` file contains the full and complete list of processor variants that are supported.

Although the API of the system services does not change between processor variants, the internals of the system services differ, depending on the specific processor variant and processor revision number being targeted. For example, the number of DMA channels for a ADSP-BF533 processor differs from the number of DMA channels for a ADSP-BF561 processor. Further, a workaround within the services for revision `x.y` of a processor may not be needed for revision `x.y` of that same processor. These differences are accounted for in the system service library module. See "System Services Overview" for more information.

Linking in the System Services Library

All object code for the system services is included in the system services library file. This file is found in the `Blackfin/lib` directory. This directory provides a system services library file for each processor variant and processor revision that is supported. You should ensure that the appropriate library is included in the list of object files for the linker.

All system service library files are of the form `libsslxxx_yyyz.dlb` where:

- `xxx` represents the processor variant – This is typically a three-digit number that identifies the processor variant, such as `532` for the ADSP-BF532 processor, `534` for the ADSP-BF534 processor, and so on.
- `_yyy` represents the operating environment – This suffix represents the targeted operating environment, such as `vdk` for VDK-based systems, `uCOS` for uCOS-based systems, and so on. Libraries built for `standalone`, specifically non-RTOS environments, do not include the `_yyy` suffix.
- `z` represents any special conditions for the library – The following combinations are used:
  - `y` – The library is built to avoid all known anomalies for all revisions of silicon.
  - blank – A library without any additional suffix does not contain workarounds to any anomalies.

  Located within the `Blackfin/lib` directory are subdirectories for individual silicon revisions. The libraries in these subdirectories are built for specific silicon revisions of the Blackfin processors.

One system services library file only should be included for the linker to process. Choose the correct library based on the processor variant, operating environment, and processor revision number for your system.

For example, an application targeting silicon revision 0.2 of the ADSP-BF532 processor without an RTOS should link with the `libss1532.dlb` file from the `Blackfin/lib/bf532_rev_0.2` subdirectory. As another example, an application developer who wants a version of the system services library to run on any revision of ADSP-BF532 silicon and uses the VDK, should link with the `libss1532_vdky.dlb` file from the `Blackfin/lib` directory.

It is strongly recommended you use the debug versions of the system services library during development because the built-in error-checking code within the library can save countless hours of development time.

Specify the use of debug versions of the libraries by selecting **Use Debug System libraries** on the **Link:Processor** page of the **Project Options** dialog box.

Rebuilding the System Services Library

Under normal situations, there is no need to rebuild the system services library. However, to accommodate unforeseen circumstances and provide developers with the ability to tailor the system services to their particular needs, all source code and include files necessary to rebuild the system services library are provided. In addition, VisualDSP++ project files are included for application developers using the VisualDSP++ development toolset.

All code for the system services library is located in the following directories:

- `Blackfin/lib` – This directory contains the Analog Devices built versions of the system service library files (`*.dlb`).
- `Blackfin/lib/src/services` – This directory contains all the source code files and non-API include files for the system services. This directory also contains the VisualDSP++ project files that can be used to rebuild the libraries.
- `Blackfin/include/services` – This directory contains all API include files for the system services.

VisualDSP++ users can simply rebuild the system services library by using the `build` command after opening the appropriate VisualDSP++ project file.

To rebuild the libraries using other development toolsets:

1. Set the preprocessor include path to include `Blackfin/include/services` and `blackfin/lib/src/services`.
2. Define the processor variant according to the definitions in the `services.h` file.
3. Define the silicon revision macro, `__SILICON_REVISION__`, to the proper value. Refer to the description of the `_si_revision` switch in your processor's *C/C++ Compiler and Library* manual for more information.
4. Compile/assemble all files in the `Blackfin/lib/src/services` directory.
5. Link the appropriate compiled/assembled objects into a library. Include all object files without any operating environment extension (such as `VDK`) and all object files with the appropriate operating environment extension specific for the environment being targeted (such as `VDK`).

Examples

The system services distribution includes many examples that illustrate how to use the system services. Refer to these examples for additional information on how to use the system services effectively.

Dual-Core Considerations

For information on how to use the system services on dual-core ADSP-BF561 processors, see "Dual-Core Considerations" on page 3-5.

RTOS Considerations

Deployment of system services and the device driver model within an application based around an RTOS, such as VDK, is highly recommended. However, observe these considerations to avoid conflict with the RTOS and to successfully deploy the system services and device drivers within a multi-threaded application.

The following discussion, which is limited to VDK, is also relevant to other RTOS environments.

Interoperability of System Services With VDK

There are three major considerations to keep in mind when deploying system services and the device driver model within a VDK-based application.

- Interrupt handling – The interrupt manager is a cornerstone of the system services and the device driver model. The interrupt manager is designed to manage only the interrupt vector groups (IVG) that it is requested to manage, as dictated by each call to `adi_int_CECHook()`, leaving the other IVG levels to be handled as per the user's requirements. Thus, VDK-managed interrupts can easily coexist alongside those managed by system services, provided that neither method manages the same IVG levels as the other. It is not possible to have a VDK ISR and an interrupt manager chain assigned to the same IVG level, as one will overwrite the other in the event vector table (EVT).

  All DMA channels and device drivers use the default IVG levels as defined in the `SIC_IARx` registers at the time of device initialization (that is, during the call to `adi_dev_Open()`).

- Prohibited interrupt levels – Appendix A of the *VisualDSP++ 5.0 Kernel (VDK) User's Guide* details four interrupt levels [EVT3 (EVX), EVT6 (IVTMR), IVG14, and IVG15] which are reserved for exclusive use by VDK and must not be managed by the interrupt manager. IVG15 is also excluded from most VisualDSP++ applications as it is used to run the applications in supervisor mode.

- Deferred callbacks – The deferred callback manager offers a similar service to the VDK process running at IVG14. It is highly recommended that the VDK variant of the system services library is used (and indeed the default VDK `.ldf` files ensure its use). This variant essentially passes callbacks posted to the DCB manager to the VDK level 14 process. In this mode of operation, only one callback queue can be used. If the standalone library variant is used, several queues can be managed but none of them can be assigned to the IVG 14 level as this would conflict with the VDK process running at that level.

Deployment of Services Within a Multi-Threaded Application

Bear in mind these two major considerations when deploying system services and the device driver model within a multi-threaded application.

- Critical regions – System services and device drivers use critical regions where atomicity of a code segment is required. These regions are managed through calls to the `adi_int_EnterCriticalRegion` function and the `adi_int_ExitCriticalRegion` function, which are defined in the `adi_int_xxx.c` files within the installation. (For more information, see “Interrupt Manager” on page 2-1.) It is advised that the above functions are used within threads that use system services rather than the VDK push/pop critical region functions.

- Initialization – Initialization of system services and the device manager is performed only once per application. Since their use may be required in several threads, it is important that the initialization is performed prior to any subsequent use. In addition, all device drivers that need to adjust their timing values according to the peripheral clock (SCLK) frequency must employ a call to `adi_pwr_GetFreq()` to determine the frequency (in Hz). The power management module must be initialized prior to the opening of any device driver.

There are basically three approaches that can be adopted:

- Define a function to initialize the system services and device manager and call it from a user-modifiable section of the "start" routine in `<Project>_basiccrt.s`.
- Assign the initialization to the highest-priority boot thread.
- Use a separate boot thread to perform the initialization and set it at the highest priority and let it yield to other threads once completed or be destroyed. Use global and not thread memory to initialize the system services and device manager in this way.

Device Driver Overview

Device drivers provide a mechanism for applications to control a device effectively. Devices may be on-chip or off-chip hardware devices, or even software modules that are best managed as virtual devices. Device drivers are typically constructed such that the application is insulated from the nuances of the hardware (or software) being controlled. In this way, both the device drivers and the devices that are being controlled can be updated or replaced without affecting the application.

The Analog Devices device driver model provides a simple, convenient method for applications to control devices commonly found in and around Analog Devices processors. It has also provides a simple and efficient mechanism for the creation of new device drivers.

The system services overview covers the following topics:

- "Application Interface" on page 1-20
- "Device Driver Architecture" on page 1-21
- "Initialization" on page 1-23
- "Termination" on page 1-24
- "Device Driver Directory and File Structure" on page 1-24

Application Interface

The device driver model provides a consistent, simple, and familiar application programming interface (API) for device drivers. All devices drivers that conform to the model use the same simple interface into the driver.

Most devices receive and/or transmit data, sometimes transforming the data in the process. This data is encapsulated in a buffer. The buffer may contain small bits of data, such as for a UART-type device that processes one character at a time, or large pieces of data, such as a video device that processes NTSC frames of approximately 1 MB in size. Applications typically provide the buffers to the device, though it is possible for devices to pass buffers from one device to another without any application involvement.

The actual API is a model-compliant driver that consists of the following basic functions:

- `adi_dev_Open()` – Opens a device for use.
- `adi_dev_Close()` – Closes down a device.
- `adi_dev_Read()` – Provides a device with buffers for inbound data.

- `adi_dev_Write()` – Provides a device with buffers for outbound data.
- `adi_dev_Control()` – Sets/detects control and status parameters for a device.

Similar to the system service APIs, the device driver API is designed to be called using the standard calling interface of the development toolset's C run-time model. The device driver API can be called by any C or assembly language program that adheres to the calling conventions and register usage of the C run-time model.

Device Driver Architecture

The device driver model separates the functionality of device drivers into two main components: the device manager and the physical drivers.

The *device manager* is a software component that provides much of the functionality common to the vast majority of device drivers. For example, depending on how the application wants the device driver to operate, the application may command a device driver to operate in synchronous mode or asynchronous mode.

In synchronous mode, when the application calls the `adi_dev_Read()` or `adi_dev_Write()` API function to read data from or send data to the device, the API function does not return to the application until the operation has completed. In asynchronous mode, the API function returns immediately to the application, while the data is moved in the background. It would be wasteful to force each physical driver to provide logic that operates both synchronously and asynchronously. The device manager provides this functionality, relieving each physical driver from reimplementing this capability.

The device manager architecture is illustrated in Figure 1-2.

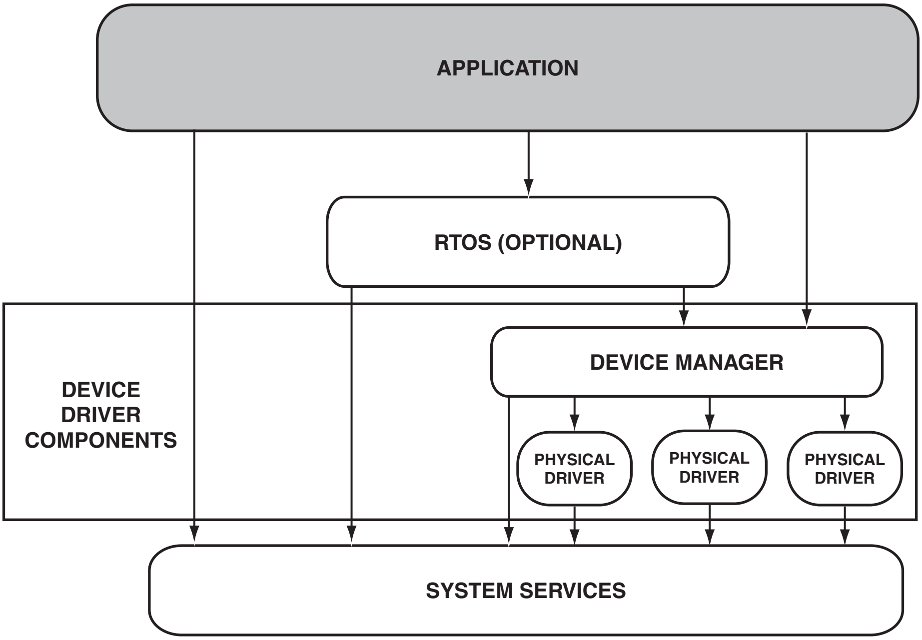


Figure 1-2. Device Manager Architecture

The device manager also provides the API to the application for each device driver. This ensures that the application has the same consistent interface regardless of the peculiarities of each device.

While there is only one device manager in a system, there can be any number of physical drivers in a system. A *physical driver* is that component of a device driver that accesses and controls the physical device. The physical driver is responsible for all the "bit banging" and control and status register manipulations of the physical device. All device-specific information is contained and isolated in the physical driver.

Interaction With System Services

As shown in Figure 1-2, the device driver model leverages the capabilities of the system services. Each software component in the system (whether it is the application, RTOS (if present), the device manager, or each physical driver) can access and call into the system services API.

The benefits of using this approach are enormous. In addition to code size and data memory savings, this approach provides each software component with access to the resources of the system and processor in a cooperative manner. Further, the amount of development effort for physical drivers is substantially reduced because each driver does not have to reimplement any of the functionality provided by the device manager or system services.

Initialization

Prior to accessing any individual driver, the device manager must first be initialized. The initialization function, `adi_dev_Init()`, is called by the application to set up and initialize the device manager.

Though the device driver model is dependent upon system services, the initialization function of the device manager does not rely on any of the system services. As such, the current revision of the device manager can be initialized before or after the system services initialization.

However, future versions of the device manager initialization function may require some of the system services capabilities. As such, it is good practice to initialize the required system services prior to initializing the device manager. Refer to the "Initialization" on page 1-10 for information on system services initialization.

Termination

The API of the device driver model includes a termination function that may be called by the application if the device drivers are no longer required. The termination function, `adi_dev_Terminate()`, is called to free up the resources used by the device manager and any open physical drivers. Many embedded systems run in an endless operating loop and never call the termination function of the device manager. An application that operates in an endless loop can save program memory by not calling the terminate function.

As part of the termination function processing, the device manager closes all open physical drivers. The physical drivers are closed in an abrupt manner. If a more graceful shutdown is needed, the application may prefer to close any open physical drivers first, and then call the termination function.

Note that because of the reliance on the system services, the termination function of the device manager should be called prior to any termination functions of the system services. This ensures that the system services can be called by the device manager and/or physical drivers as part of their shutdown procedure.

After the device manager has been terminated, it must be reinitialized before any of its functionality can be accessed again.

Device Driver Directory and File Structure

All files for the device driver model are contained within the `Blackfin` directory tree. In VisualDSP++ installations, this is the directory that stores the core development tools. Other development toolsets may use other directory names for their toolkits, but the device driver files can always be found within the `Blackfin` directory tree.

To use the device drivers, applications need only to use include files in their source code, and link with a device driver library and a system services library module.

Accessing the Device Driver API

User source files accessing the device manager API should include the files `services.h` and `adi_dev.h`, located in the `Blackfin/include/services` and `Blackfin/include/drivers` directories, respectively. In addition, your source file should use the include file of the physical driver that will be accessed.

For example, user code that accesses the Analog Devices parallel peripheral interface (PPI) driver would include the following lines in their source file (in order):

```
#include <services/services.h>          // system services
#include <drivers/adi_dev.h>            // device manager
#include <drivers/ppi/adi_ppi.h>        // PPI physical driver
```

The device driver API and functionality is uniform and consistent across all Blackfin processors, including all single- and multi-core devices. Regardless of the Blackfin processor being targeted, application software does not change. For example, application software running on a single-core ADSP-BF533 processor can operate unchanged on a multi-core ADSP-BF561 processor.

In order to provide this consistent API to the application, the system services, device manager, and physical drivers need to be aware of the specific processor variant being targeted. You must ensure that the processor definition macro for the processor variant being targeted is defined when including the system services (`services.h`), device manager (`adi_dev.h`), and physical driver include files.

The VisualDSP++ toolset automatically sets the processor definition macro when building projects. Application developers using the VisualDSP++ toolset need do nothing further to ensure the processor definition macro is defined.

Application developers using other toolsets, however, should ensure that the processor definition macro is appropriately defined. The `services.h` file enumerates the specific processor variants that are supported. These processor variants include:

`__ADSPBF531__`	The ADSP-BF531 processor
`__ADSPBF532__`	The ADSP-BF532 processor
`__ADSPBF533__`	The ADSP-BF533 processor
`__ADSPBF534__`	The ADSP-BF534 processor
`__ADSPBF535__`	The ADSP-BF535 processor
`__ADSPBF536__`	The ADSP-BF536 processor
`__ADSPBF537__`	The ADSP-BF537 processor
`__ADSPBF538__`	The ADSP-BF538 processor
`__ADSPBF539__`	The ADSP-BF539 processor
`__ADSPBF561__`	The ADSP-BF561 processor

The `services.h` file contains the full and complete list of processor variants that are supported by the system services. The `adi_dev.h` file contains the list of processor families that are supported by the device driver model.

Device Driver File Locations

Device drivers for on-chip peripherals are provided in the `libdrvxxx.dlb` library for the various processor derivatives, silicon revisions, and so on. Device drivers for off-chip peripherals are not provided within the library, but rather must be included separately with the application. Include files for off-chip peripheral drivers are included in following subdirectories:

```
$ADI_DSP\Blackfin\include\drivers
```

where `$ADI_DSP` is the location of your VisualDSP installation, which is, by default, located at:

`C:\Program Files\Analog Devices\VisualDSP` *<version>*

Source files for off-chip peripheral drivers are included in subdirectories:

```
$ADI_DSP\Blackfin\lib\src\drivers
```

When creating applications that include off-chip device drivers, the application should include the `.h` file for the driver. This is typically done with something like this:

```
#include <drivers\codec\adi_ad1836.h>
```

The source code for an off-chip peripheral driver should be included in the source file list of the VisualDSP++ project. For example, if using the AD1836 device driver, the file

```
$ADI_DSP\Blackfin\lib\src\drivers\codec\adi_ad1836.c
```

should be included in the source file list.

Linking in the Device Driver Library

All object code for the device manager and Analog Devices-supplied physical drivers is included in the device driver library file. This file is found in the `Blackfin/lib` directory. In this directory is a device driver library file for each supported processor variant. You should ensure that the appropriate library is included in the list of object files for the linker.

The device driver library file is of the form `libdrvxxxz.dlb` where:

- `xxx` represents the processor variant – This is typically a three-digit number that identifies the processor variant, such as `532` for the ADSP-BF532 processor, `534` for the ADSP-BF534 processor, and so on.
- `z` represents any special conditions for the library – The following combinations are used:
    - `y` – The library is built to avoid all known anomalies for all revisions of silicon.
    - blank – A library without an additional suffix does not contain workarounds to any anomalies.

Located within the `Blackfin/library` directory are subdirectories for individual silicon revisions. The libraries in these subdirectories are built for specific silicon revisions of the processors.

One device driver library file should be included for the linker to process. Choose the correct library based on the processor variant for your system.

For example, an application developer targeting silicon revision 0.2 of the ADSP-BF532 processor should link with the `libdrv532.dlb` file from the `Blackfin/lib/bf532_rev_0.2` subdirectory. As another example, the application developer who wants a version of the device driver library that will run on any revision of ADSP-BF532 silicon should link with the `libdrv532y.dlb` file from the `Blackfin/lib` directory.

It is strongly recommended that you use the debug versions of the device driver library during development, because built-in, error-checking code within the library can save countless hours of development time.

Specify the use of debug versions of the libraries by selecting **Use Debug System libraries** on the **Link:Processor** page of the **Project Options** dialog box.

Rebuilding the Device Driver Library

Under normal situations, there is no need to rebuild the device driver library. However, to accommodate unforeseen circumstances and provide the ability to tailor the implementation to a user's particular needs, all source code and include files necessary to rebuild the device driver library are provided. In addition, VisualDSP++ project files are included for application developers who use the VisualDSP++ development toolset.

All code for the device driver library is located in the following directories:

- `Blackfin/lib` – This directory contains the Analog Devices-built versions of the device driver library files (`*.dlb`).
- `Blackfin/lib/src/drivers` – This directory contains all the source code files and non-API include files for the device manager and Analog Devices-provided physical drivers. Also in this directory are VisualDSP++ project files that can be used to rebuild the libraries.
- `Blackfin/include/drivers` – This directory contains the device manager API include file and the include files for all Analog Devices-provided physical drivers.

VisualDSP++ users can rebuild the device driver library by using the `build` command after opening the appropriate VisualDSP++ project file.

To rebuild the libraries using other development toolsets:

1. Set the preprocessor include path to include `Blackfin/include/drivers` and `Blackfin/lib/src/drivers`.
2. Define the processor variant according to the definitions in the `services.h` file.
3. Define the silicon revision macro, `__SILICON_REVISION__`, to the proper value. Refer to the compiler's `-si-revision` switch for more information.
4. Compile/assemble all files in the `Blackfin/lib/src/drivers` directory.
5. Link the appropriate compiled/assembled objects including all object files into a library.

Examples on Distribution

The device driver distribution includes examples that illustrate how to use the device drivers. Refer to these examples for additional information on how to use the device drivers effectively.

2 INTERRUPT MANAGER

This chapter describes the interrupt manager that controls and manages the interrupt and event operations of the Blackfin processor.

This chapter contains:

Introduction

The Blackfin processor employs a two-tiered mechanism for controlling interrupts and events. System-level interrupts are controlled by the *system interrupt controller* (SIC). All peripheral interrupt signals are routed through the system interrupt controller and then, depending on the settings of the system interrupt controller, routed to the *core event controller* (CEC). The core event controller processes these events and, depending on the settings of the core event controller, vectors the processor to handle the events.

The interrupt manager provides functions that allow the application to control every aspect of the system interrupt controller and the core event controller. It does this so that events and interrupts are handled and processed in an efficient, yet cooperative, manner.

The Blackfin processor provides 16 levels of interrupt and events. These levels, called *interrupt vector groups* (IVG), are numbered from 0 to 15, with the lowest number having the highest priority. Some IVG levels are dedicated to certain events, such as emulation, reset, *non-maskable interrupt* (NMI, and so on. Other IVG levels, specifically levels 7 through 15, are considered general-purpose events and are typically used for system-level (peripheral) interrupts or software interrupts.

All IVG processing is performed in the CEC. When a specific IVG is triggered, assuming the event is enabled, the CEC looks up the appropriate entry in the event vector table and vectors execution to the address in the table where the event is processed.

All system or peripheral interrupts are first routed through the SIC. Assuming the SIC has been programmed, peripheral interrupts are then routed to the CEC for processing. The SIC provides a rich set of functionality for the processing and handling of peripheral interrupts. In addition to allowing/disallowing peripheral interrupts to be routed to the CEC, the

SIC allows peripheral interrupts to be mapped to any of the CEC's general-purpose IVG levels and controls whether these interrupts wake the processor from an idled operating mode.

In systems that employ Blackfin processors, often there are more potential interrupt sources than IVG levels. As stated above, some events (such as NMI) map one-to-one to an IVG level. Other events, typically infrequent interrupts such as peripheral error interrupts, are often "ganged" in a single IVG level.

The interrupt manager allows the application to execute complete control over how interrupts are handled, whether they are masked or unmasked, whether they mapped one-to-one or ganged together, whether the processor should be awakened to service an interrupt, and so on. The interrupt manager also allows the creation of *interrupt handler* chains. An interrupt handler is a C-callable function that is provided by the application to process an interrupt. Through the interrupt manager, the application can hook in any number of interrupt handlers for any IVG level. When multiple events are ganged to a single IVG level, this allows each handler to be designed independently from any other and allows the application to process these interrupts in a straightforward manner.

Further, the interrupt manager processes only those IVG levels and system interrupts that the application directs the interrupt manager to control. This allows the application developer to have complete unfettered access to any IVG level or system interrupt to manually control interrupts.

Multi-core Blackfin processors extend this capability by including one system interrupt controller and one core event controller for each core. This provides maximum flexibility by allowing application developers to decide how to map interrupts to individual cores, multiple cores, and so on. When using multi-core Blackfin processors, typically one interrupt manager for each core is used. Because there is no reason to provide multiple interrupt managers on single-core devices, this service is not supported. Application developers should not attempt to instantiate more than one interrupt manager per core.

Following the convention of all the system services, the interrupt manager uses a unique and unambiguous naming convention to guard against conflicts. All enumeration values, `typedef` statements and macros use the `ADI_INT_` prefix, while all functions within the interrupt manager use the `adi_int_` prefix.

All interrupt manager API functions return the `ADI_INT_RESULT` return code. See the `adi_int.h` file for the list of return codes. Like all system services, the return code that signals successful completion, `ADI_INT_RESULT_SUCCESS` for the interrupt manager, is defined to be 0. This allows applications to quickly and easily determine whether any errors occurred in processing.

Interrupt Manager Initialization

To use the interrupt manager, a function must initialize the interrupt manager. The function that initializes the interrupt manager is called `adi_int_Init`. The application that calls `adi_int_Init` passes an argument defining the memory that the interrupt manager uses when operating.

The amount of memory provided depends on the number of secondary handlers used by the application. When using interrupt handler chaining, the interrupt manager considers the first interrupt handler that is hooked into an IVG level to be the primary interrupt handler. Any additional interrupt handlers that hooked into that same IVG level are considered secondary handlers. Without any additional memory from the application, the interrupt manager can support one primary interrupt handler for each IVG level. If the application never has more than one interrupt handler on each IVG level (that is, only the primary interrupt handler and no secondary handlers are present), the application does not need to provide memory to the interrupt manager's initialization function. However, if the application hooks in secondary interrupt handlers, the application must provide additional memory to support the secondary handlers.

The ADI_INT_SECONDARY_MEMORY macro is defined to be the amount of memory (in bytes) required to support a single secondary handler. Thus, the application should provide to the initialization function “n” times ADI_INT_SECONDARY_MEMORY, where “n” is the number of secondary handlers that are supported.

Another parameter passed to the initialization function is the parameter that the interrupt manager passes to the adi_int_EnterCriticalRegion() function. This value depends upon the operating environment of the application. See the adi_int_EnterCriticalRegion function for more information.

When called, the initialization function initializes its internal data structures and returns. No changes are made to the CEC or SIC during initialization. After initialization, any other interrupt manager API functions may be called.

Interrupt Manager Termination

When the functionality of the interrupt manager is no longer required, the application can call the termination function of the interrupt manager, adi_int_Terminate(). Many applications operate in an endless loop and never call the termination function.

When called, the termination function unhooks all interrupt handlers, masking off (disabling) all interrupts the that the interrupt manager was controlling. After calling the termination function, any memory provided to the initialization function may be reused by the application. No other interrupt manager functions can be called after termination. If interrupt manager services are required after the termination function is called, the application must reinitialize interrupt manager services by calling the adi_pwr_Init function.

Core Event Controller Functions

Only two functions are necessary to provide complete control over the core event controller (CEC): `adi_int_CECHook()` and `adi_int_CECUnhook()`, as described next.

adi_int_CECHook() Function

The `adi_int_CECHook()` function is used to hook an interrupt handler into the handler chain for an IVG level. When called, the application passes in the IVG number to be handled, the address of the handler function, a parameter that the interrupt manager automatically passes back to the interrupt handler when the interrupt handler is invoked, and a flag indicating whether interrupt nesting should be enabled for this IVG level.

The handler function itself is a simple C-callable function that conforms to the `ADI_INT_HANDLER_FN typedef`. The interrupt handler is not an interrupt service routine (ISR) but a standard C-callable function. When the IVG level triggers it, the interrupt manager calls the interrupt handler to process the event. The interrupt manager passes the client argument that was passed to the interrupt manager via the `adi_int_CECHook()` function to the interrupt handler. The interrupt handler takes whatever action is necessary to process the interrupt, then returns with either the `ADI_INT_RESULT_PROCESSED` or `ADI_INT_RESULT_NOT_PROCESSED` return code.

Interrupt handlers should be written such that they interrogate the system quickly when determining whether the event that triggered the interrupt should be processed by the interrupt handler. If the event that caused the interrupt is not the event the interrupt handler was expecting, it should immediately return with the `ADI_INT_RESULT_NOT_PROCESSED` return code. The interrupt manager then automatically invokes the next interrupt handler, if any, that is hooked into the same IVG level. If the event that caused the interrupt is expected by the interrupt handler, the interrupt handler performs whatever processing is necessary and should return the `ADI_INT_RESULT_PROCESSED` return code.

The nesting flag parameter is of significance only when the first interrupt handler is hooked into an IVG chain. The first interrupt handler that hooks into an IVG chain is called the *primary handler*. Any additional handlers that are hooked into that same IVG chain are called *secondary handlers*. When the primary handler is hooked into the chain, the interrupt manager loads an ISR into the appropriate entry of the event vector table (EVT). If the nesting flag is set, the ISR that the interrupt manager loads is one that supports interrupt nesting. If the nesting flag is clear, the ISR that the interrupt manager loads is one that does not support interrupt nesting. When secondary handlers are hooked into an IVG chain, the nesting flag is ignored.

Lastly, the `adi_int_CECHook()` function unmasks the appropriate bit in the CEC's `IMASK` register, thereby enabling the interrupt to be processed.

In most applications, users take great care to optimize the processing that occurs for the highest frequency and highest urgency interrupts. Typically, the highest frequency or highest urgency interrupts are assigned their own IVG level, and less frequent or lower urgency interrupts (such as error processing) are ganged together on a single IVG level.

The interrupt manager continues that thinking and has been optimized to allow extremely efficient processing for primary interrupt handlers. Though still efficient, secondary handlers are called after the primary handler. Secondary handlers are hooked into the IVG chain in a stacked or last-in, first-out (LIFO) fashion. This means that when an event is triggered, after calling the primary handler (and assuming the primary handler did not return the `ADI_INT_RESULT_PROCESSED` return code), the interrupt manager calls the last secondary handler that was hooked, followed by the second to last installed handler, and so on.

To ensure optimal performance, the application developer should manage which interrupt handlers are hooked as primaries and which are hooked as secondary handlers.

adi_int_CECUnhook() Function

The `adi_int_CECUnhook()` function is used to unhook an interrupt handler from the interrupt handler chain for a particular IVG level. When called, the application passes in the IVG number and the address of the interrupt handler function to be unhooked from the chain.

The function removes the interrupt handler from the chain of handlers for the given IVG level. If the primary handler is being removed, the last secondary handler that was hooked becomes the new primary handler. If, after removing the given interrupt handler, no interrupt handlers are left in the IVG chain, the `adi_int_CECUnhook()` function masks the appropriate bit in the CEC's `IMASK` register, thereby disabling the interrupt.

Interrupt Handlers

Since the interrupt handlers registered with the interrupt manager are invoked from within the built-in IVG interrupt service routine (and there may be several interrupts pending for the same IVG level), individual interrupt handlers must not invoke the `RTI` instruction on completion. Instead, they should return using the `RTS` return function. Interrupt handlers are in fact nothing more than typical C-callable subroutines.

Therrefore, each peripheral interrupt handler must conform to the following template,

```
ADI_INT_HANDLER(mjk_SPORT_RX_handler)
{
 ...     ...          // user code
}
```

where the ADI_INT_HANDLER macro is defined as

```
#define ADI_INT_HANDLER(NAME) \
        void (*NAME)(void *ClientArg)
```

System Interrupt Controller Functions

The following functions are provided to give the application complete control over the system interrupt controller:

- adi_int_SICEnable – Enables peripheral interrupts to be passed to the CEC.
- adi_int_SICDisable – Disables peripheral interrupts from being passed to the CEC.
- adi_int_SICSetIVG – Sets the IVG level to which a peripheral interrupt is mapped.
- adi_int_SICGetIVG – Detects the IVG level to which a peripheral interrupt is mapped.
- adi_int_SICWakeup – Establishes whether a peripheral interrupt wakes up the processor from an idled state.
- adi_int_SICInterruptAsserted – Detects whether a peripheral interrupt is asserted.

All SIC functions take as a parameter an enumeration value that uniquely identifies a peripheral interrupt. The ADI_INT_PERIPHERAL_ID enumeration identifies each possible peripheral interrupt source for the processor. This enumeration is defined in the adi_int.h file. Refer to this header file for the complete list of values for each supported Blackfin processor.

adi_int_SICDisable

The `adi_int_SICDisable()` function is used to disable a peripheral interrupt from being passed to the core event controller. When called, this function programs the appropriate SIC `IMASK` register to disable the given peripheral interrupt.

adi_int_SICEnable

The `adi_int_SICEnable()` function is used to enable a peripheral interrupt to be passed to the core event controller. When called, this function programs the appropriate SIC `IMASK` register to enable the given peripheral interrupt.

adi_int_SICGetIVG

The `adi_int_SICGetIVG()` function is used to detect the IVG level to which a peripheral interrupt is mapped.

In addition to the `ADI_INT_PERIPHERAL_ID` parameter, this function is passed pointer-to-memory location information. The function interrogates the proper field of the appropriate SIC interrupt assignment register and stores the IVG level (0 to 15) to which the given peripheral interrupt is mapped into the memory location.

adi_int_SICInterruptAsserted

The `adi_int_SICInterruptAsserted()` function is used to detect whether the given peripheral interrupt is asserted. Though it can be called at any time, it is intended that this function is called immediately by the application's interrupt handlers to determine if a given peripheral interrupt is being asserted, allowing the interrupt handler to determine if its peripheral is asserting the interrupt.

Instead of using the usual ADI_INT_RESULT_SUCCESS return code, this function returns the ADI_INT_RESULT_ASSERTED or ADI_INT_RESULT_NOT_ASSERTED return code upon a successful completion. If errors are detected with the calling parameters, this function may return a different error code.

adi_int_SICSetIVG

The adi_int_SICSetIVG() function is used to set the IVG level to which a peripheral interrupt is mapped. Upon power-up, the Blackfin processor invokes a default mapping of peripheral interrupts to the IVG level. This function alters that mapping. In addition to the ADI_INT_PERIPHERAL_ID parameter, this function is passed to the IVG level (0 to 15) to which the peripheral interrupt should be mapped. The function modifies the proper field within the appropriate SIC interrupt assignment register to the new mapping.

adi_int_SICWakeup

The adi_int_SICWakeup() function is used to enable or disable a peripheral interrupt from waking up the core when the interrupt trigger and the core are in an idled state. In addition to the ADI_INT_PERIPHERAL_ID parameter, this function is passed a TRUE/FALSE flag. If the flag is TRUE, the SIC interrupt wakeup register is programmed such that the given peripheral interrupt wakes up the core when the interrupt is triggered. If the flag is FALSE, the SIC interrupt wakeup register is programmed such that the given peripheral interrupt does not wake up the core when the interrupt is triggered.

Note that this function does not enable or disable interrupt processing. Also note that it is possible to configure the SIC so that a peripheral interrupt wakes up the core from an idled state but does not process the interrupt. This may or may not be the intended operation.

Protecting Critical Code Regions

In embedded systems, it is often necessary to protect a critical region of code while it is being executed. This is often necessary while one logical programming sequence is updating or modifying a piece of data. In these cases, another logical programming sequence, such as interrupt processing in one system (or different thread in an RTOS-based system) is prevented from interfering while the critical data is being updated.

To that end, the interrupt manager provides two functions that can be used to bracket a critical region of code: `adi_int_EnterCriticalRegion()` and `adi_int_ExitCriticalRegion()`. The application calls the `adi_int_EnterCriticalRegion()` function at the beginning of the critical section of code, and then calls the `adi_int_ExitCriticalRegion()` function at the end of the critical section. These functions must be used in pairs.

The actual implementation of these functions varies from operating environment to operating environment. For example, in a standalone system (systems without any RTOS), what actually happens in these functions may be different than the version of these functions for an RTOS-based system. The principle and usage, however, are the same, regardless of implementation. In this way, application code always operates the same way, and does not change, regardless of the operating environment.

The adi_int_EnterCriticalRegion() function is passed an argument of type void * and returns an argument of type void *. The value returned from the adi_int_EnterCriticalRegion() function must always be passed to the corresponding adi_int_ExitCriticalRegion() function. For example, examine the following code sequence:

```
...
Value = adi_int_EnterCriticalRegion(pArg);
...                              // critical section of code
adi_int_ExitCriticalRegion(Value);
...
```

The value returned from the adi_int_EnterCriticalRegion() function must be passed to the corresponding adi_int_ExitCriticalRegion() function. Although nesting of calls to these functions is allowed, the application developer minimizes the use of these functions to only those critical sections of code, and realizes that in all likelihood, the processor is being placed in some altered state. This could affect the performance of the system, while in the critical regions.

For example, it could be that interrupts are disabled in the critical region. The application developer typically does not want to have interrupts disabled for long periods of time. These functions should be used sparingly and judiciously.

Nesting of these calls is allowed. For example, consider the following code sequence that makes a call to the Foo() function while in a critical section of code. The Foo() function also has a critical region of code.

```
...
Value = adi_int_EnterCriticalRegion(pArg);
...          // critical section of code
Foo();       // call to Foo()
adi_int_ExitCriticalRegion(Value);
...
```

```
void Foo(void) {
void *Value;
...
Value = adi_int_EnterCriticalRegion(pArg);
...             // critical section of code
adi_int_ExitCriticalRegion(Value);
...
}
```

This practice is allowed; however, the application developer is cautioned that overuse of these functions can affect system performance.

The `pArg` value passed into the `adi_int_EnterCriticalRegion()` function depends upon the actual implementation for the given operating environment. In some operating environments, the value is not used and can be NULL. For more information on the `pArg` parameter, check the source file for the specific operating environment, `adi_int_xxx.c`, in the `Blackfin/lib/src/services` directory where `xxx` is the operating environment.

ⓘ All system services and device drivers use these functions exclusively to protect critical regions of code. Application software should also use these functions exclusively to protect critical regions of code within the application.

Modifying IMASK

Though applications rarely need to have the processor's `IMASK` register value modified, the interrupt manager itself modifies the `IMASK` register value to control the CEC properly. In some RTOS-based operating environments, the RTOS controls the `IMASK` register tightly and provides functions that allow the manipulation of `IMASK`.

In order to ensure compatibility across all operating environments, the interrupt manager provides functions that allow bits within the `IMASK` register to be set or cleared. Depending on the operating environment, these functions may modify the IMASK value directly, or use the RTOS-provided IMASK manipulation functions. Regardless of how the IMASK value is changed, the interrupt manager API provides a uniform and consistent mechanism for this.

Two operating environment implementation-dependent functions are provided to set and clear bits in the IMASK register: adi_int_SetIMASKBits and adi_int_ClearIMASKBits. These functions take as a parameter a value that corresponds to the IMASK register of the targeted processor. When the adi_int_SetIMASKBits() function is called, the function sets to 1 those bits in the IMASK register that have a 1 in the corresponding bit position of the value passed in. When the adi_int_ClearIMASKBits() function is called, the function clears those bits (to 0) in the IMASK register that have a 1 in the corresponding bit position of the value passed in.

Consider the following example code. Assume that IMASK is a 32-bit value and contains 0x00000000 upon entry into the code:

```
...
...             // IMASK = 0x00000000
ReturnCode = adi_int_SetIMASKBits(0x00000003);
...             // IMASK now equals 0x00000003
ReturnCode = adi_int_ClearIMASKBits(0x00000001);
...             // IMASK now equals 0x00000002
ReturnCode = adi_int_ClearIMASKBits(0x00000002);
...             // IMASK now equals 0x00000000
```

While it is very unlikely that the application will ever need to control individual IMASK bit values, the interrupt manager uses these functions to control the CEC.

Examples

Examples demonstrating use of the interrupt manager can be found in the Blackfin/EZ-Kits subdirectories.

File Structure

The API for the interrupt manager is defined in the adi_int.h header file. This file is located in the Blackfin/include/services subdirectory and is automatically included by the services.h file in that same directory. Only the services.h file should be included in the application code.

Applications should link with only one of the system services library files. These files are located in the Blackfin/lib directory. See the approprite section in Chapter 6, DMA Manager, for more information on selecting the proper library file.

For convenience, all source code for the interrupt manager is located in the Blackfin/lib/src/services directory. All operating environment-dependent code is located in the file adi_int_xxx.c, where xxx is the operating environment being targeted. These files should never be linked into an application because the appropriate system services library file contains all required object code.

Interrupt Manager API Reference

This section provides descriptions of the interrupt manager module's application programming interface (API) functions.

Notation Conventions

The reference pages for the API functions use the following format:

Name – Name and purpose of the function

Description – Function specification

Prototype – Required header file and functional prototype

Arguments – Description of function arguments

Return Value – Description of function return values

adi_int_Init

Description

This function sets aside and initializes memory for the interrupt manager. It also initializes other tables and vectors within the interrupt manager. This function is only called once per core. Separate memory areas are assigned for each core.

Prototype

```
ADI_INT_RESULT adi_int_Init(
        void            *pMemory,
        const size_t    MemorySize,
        u32             *pMaxEntries,
        void            *pEnterCriticalArg
);
```

Arguments

*pMemory	Pointer to an area of memory used by the interrupt manager
MemorySize	Size, in bytes, of memory supplied for the interrupt manager
*pMaxEntries	On return, this argument contains the number of secondary handler entries that the interrupt manager can support given the memory supplied.
*pEnterCriticalArg	Parameter passed to the adi_int_EnterCriticalRegion

Return Value

Return values include:

ADI_INT_RESULT_SUCCESS	Successfully initialized.

adi_int_Terminate

Description

This function closes down the interrupt manager. All memory used by the interrupt manager is freed up, all handlers are unhooked, and all interrupt vector groups (IVG) that were enabled and controlled by the interrupt manager are disabled.

> The `adi_int_Terminate` function does not alter the system interrupt controller settings. Should changes to the SIC be required, the application should make the appropriate calls into the relevant SIC control functions before calling `adi_int_Terminate()`.

Prototype

```
ADI_INT_RESULT adi_int_Terminate(void);
```

Arguments

None

Return Value

The function returns `ADI_INT_RESULT_SUCCESS` if successful. Any other value indicates an error.

adi_int_CECHook

Description

This function instructs the interrupt manager to hook (insert) the given interrupt handler into the interrupt handler chain for the given IVG.

On a return from this call, the core event controller is programmed such that the given IVG is unmasked (enabled) and the system is properly configured to service the interrupt via the interrupt manager's built-in ISRs. The ISRs then invoke the interrupt handler supplied by the caller. Depending on the state of the `NestingFlag` parameter, the interrupt manager installs its built-in interrupt service routine with interrupt nesting, either enabled or disabled.

On the first call for a given IVG level, the interrupt manager registers its built-in IVG interrupt service routine against that level and establishes the supplied interrupt handler as the primary interrupt handler for the given IVG level. Subsequent calls to `adi_int_CECHook` for the same IVG level create a chain of secondary interrupt handlers for the IVG level. When the interrupt for the IVG level is triggered, the primary interrupt handler is called first, and then if present, each secondary interrupt handler is subsequently called.

The `ClientArg` parameter provided in the `adi_int_CECHook` function is passed to the interrupt handler as an argument when the interrupt handler is called in response to interrupt generation.

Prototype

```
ADI_INT_RESULT adi_int_CECHook(
         u32                 IVG,
         ADI_INT_HANDLER_FN  Handler,
         void                *ClientArg,
         u32                 NestingFlag
);
```

Arguments

`IVG`	Interrupt vector group number being addressed
`Handler`	Client's interrupt handler inserted into the chain for the given IVG
`ClientArg`	A `void *` value that is passed to the interrupt handler
`NestingFlag`	Argument that selects whether nesting of interrupts is allowed or disallowed for the IVG (TRUE/FALSE)

Return Value

Return values include:

`ADI_INT_RESULT_SUCCESS`	Interrupt handler was successfully hooked into the chain.
`ADI_INT_RESULT_NO_MEMORY`	Insufficient memory is available to insert the handler into the chain.
`ADI_INT_RESULT_INVALID_IVG`	IVG level is invalid.

adi_int_CECUnhook

Description

This function instructs the interrupt manager to unhook (remove) the given interrupt handler from the interrupt handler chain for the given IVG.

If the given interrupt handler is the only interrupt handler in the chain, the CEC is programmed to disable (mask) the given IVG, and the interrupt manager built-in interrupt service routine is removed from the IVG entry within the event vector table.

If the chain for the given IVG contains multiple interrupt handlers, the given interrupt handler is simply purged from the chain. If the primary interrupt handler is removed and there are secondary interrupt handlers present in the chain, one of the secondary interrupt handlers becomes the primary interrupt handler.

Prototype

```
ADI_INT_RESULT adi_int_CECUnhook(
        u32                 IVG,
        ADI_INT_HANDLER_FN  Handler,
        void                *ClientArg
);
```

Arguments

`IVG`	Interrupt vector group number being addressed
`Handler`	Client's interrupt handler removed from the chain for the given IVG
`ClientArg`	A `void *` value that is passed to the interrupt handler. To remove the interrupt handler successfully, match this value to the `ClientArg` parameter that was passed to the `adi_int_CECHook()` function when the interrupt handler was hooked into the chain.

Return Value

Return values include:

`ADI_INT_RESULT_SUCCESS`	Interrupt handler was successfully unhooked from the chain.
`ADI_INT_RESULT_INVALID_IVG`	IVG level is invalid.

adi_int_ClearIMaskBits

Description

This function is used by the interrupt manager to clear bits in the IMASK register. Though it can also be called by the application, the application should not attempt to modify bits in the IMASK register that represent interrupt vector groups that are under the control of the interrupt manager.

The implementation of this function depends upon the operating environment. In the standalone version of the service, this function detects whether the processor is within a protected region of code (refer to the adi_int_EnterCriticalRegion and adi_int_ExitCriticalRegion functions, respectively). If it is, the saved value of IMASK is updated accordingly and the current "live" IMASK value is left unchanged.

When the outermost adi_int_ExitCriticalRegion function is called, the saved IMASK value with the new bit settings is restored. Upon entering this function, if the processor is not within a protected region of code, the "live" IMASK register is updated accordingly.

Information on the implementation details for this function in other operating environments can be found in the file adi_int_xxx.h, located in the Blackfin/include/services/ directory, where xxx is the operating environment.

Regardless of the implementation details, the API is consistent from environment to operating environment. Changes to application software are not required when code is moved to a different operating environment.

Prototype

```
void adi_int_ClearIMASKBits(
        ADI_INT_IMASK      BitsToClear
);
```

Arguments

`BitsToClear`	Replica of the IMASK register containing bits that are to be cleared in the real IMASK register. A bit with a value of '1' clears the corresponding bit in the IMASK register. A bit with the value of '0' leaves the corresponding bit in the IMASK register unchanged.

Return Value

None

adi_int_EnterCriticalRegion

Description

This function creates a condition that protects a critical region of code. The companion function, adi_int_ExitCriticalRegion, removes the condition. These functions are used to bracket a section of code that requires protection from other processing. These functions are used in pairs sparingly and only when critical regions of code needs to be protected.

The return value from this function should be passed to the corresponding adi_int_ExitCriticalRegion function.

The actual condition that is created depends upon the operating environment. In the standalone version of the service, this function effectively disables interrupts, saving the current value of IMASK to a temporary location. The adi_int_ExitCriticalRegion function restores the original IMASK value. These functions employ a usage counter so that they can be nested. When nested, the IMASK value is altered only at the outermost levels. In the standalone version, the pArg parameter to the adi_int_EnterCriticalRegion is meaningless.

Information on the implementation details for this function in other operating environments can be found in the file adi_int_xxx.h, located in the Blackfin/include/services/ directory, where xxx is the operating environment.

Regardless of the implementation details, the API is consistent from environment to operating environment and from processor to processor. Application software does not need to change when moving to a different operating environment or moving from one Blackfin derivative to another.

Prototype

```
void *adi_int_EnterCriticalRegion(
        void         *pArg
);
```

Arguments

pArg	Implementation dependent. Refer to the adi_int_xxx.h file for details on this parameter for the xxx environment.

Return Value

The return value from this function should always be passed to the corresponding adi_int_ExitCriticalRegion function.

adi_int_ExitCriticalRegion

Description

This function removes the condition that was established by the `adi_int_EnterCriticalRegion` to protect a critical region of code. These functions are used to bracket a section of code that needs protection from other processing. These functions are used sparingly and only when critical regions of code require protection.

The `pArg` parameter that is passed to this function should always be the return value from the corresponding `adi_int_EnterCriticalRegion` function.

See the `adi_int_EnterCriticalRegion` function for more information.

Prototype

```
void adi_int_ExitCriticalRegion(
        void      *pArg
);
```

Arguments

`pArg`	Return value from the corresponding `adi_int_EnterCriticalRegion()` function call

Return Value

None

adi_int_SICDisable

Description

This function configures the system interrupt controller to disable the given interrupt and prevent it from being passed to the core event controller.

The `adi_int_SICDisable` function simply programs the system interrupt mask register to mask interrupts from the given peripheral, thereby preventing them from being passed to the core event controller.

Prototype

```
ADI_INT_RESULT adi_int_SICDisable(
        const ADI_INT_PERIPHERAL_ID   PeripheralID
);
```

Arguments

`PeripheralID`	`ADI_INT_PERIPHERAL_ID` enumeration value that identifies an interrupt source

Return Value

`ADI_INT_RESULT_SUCCESS`	System interrupt controller has been successfully configured.
`ADI_INT_RESULT_INVALID_PERIPHERALID`	Peripheral ID specified is invalid.

adi_int_SICEnable

Description

This function configures the system interrupt controller to enable the given interrupt and allow it to pass to the core event controller.

The `adi_int_SICEnable` function simply programs the system interrupt mask register to allow interrupts from the given peripheral to be passed to the core event controller.

Prototype

```
ADI_INT_RESULT adi_int_SICEnable(
        const ADI_INT_PERIPHERAL_ID    PeripheralID,
);
```

Arguments

`PeripheralID`	`ADI_INT_PERIPHERAL_ED` enumeration value that identifies a peripheral interrupt source

Return Value

Return values include:

`ADI_INT_RESULT_SUCCESS`	System interrupt controller has been successfully configured.
`ADI_INT_RESULT_INVALID_PERIPHERAL_ID`	Peripheral ID specified is invalid.

adi_int_SICGetIVG

Description

This function detects the mapping of a peripheral interrupt source to an IVG level. When called, this function reads the appropriate system interrupt assignment register(s) of the given peripheral and stores the IVG level to which the peripheral is mapped into the location provided by the application. This function does not modify any parameters of the interrupt controller.

Prototype

```
ADI_INT_RESULT adi_int_SICSetIVG(
        const ADI_INT_PERIPHERAL_ID   PeripheralID,
        u32                           *pIVG
);
```

Arguments

PeripheralID	ADI_INT_PERIPHERAL_ID enumeration value that identifies a peripheral interrupt source
*pIVG	Pointer to an unsigned 32-bit memory location into which the function writes the IVG level to which the given peripheral is mapped

Return Value

The function returns ADI_INT_RESULT_SUCCESS if successful. Other possible return values include:

ADI_INT_RESULT_INVALID_PERIPHERAL_ID	Peripheral ID specified is invalid.
ADI_INT_RESULT_INVALID_IVG	Interrupt vector group level is invalid.

adi_int_SICInterruptAsserted

Description

This function determines whether a given peripheral interrupt source is asserting an interrupt. This function is typically called in an application's interrupt handler to determine whether the peripheral in question is asserting an interrupt. This function does not modify any parameters of the interrupt controller but simply interrogates the appropriate interrupt status register(s).

Prototype

```
ADI_INT_RESULT adi_int_SICInterruptAsserted(
        const ADI_INT_PERIPHERAL_ID   PeripheralID
);
```

Arguments

PeripheralID	ADI_INT_PERIPHERAL_ID enumeration value that identifies a peripheral interrupt source

Return Value

The function returns one of the following values:

ADI_INT_RESULT_INVALID_PERIPHERAL_ID	Peripheral ID specified is invalid.
ADI_INT_RESULT_ASSERTED	Specified peripheral is asserting an interrupt.
ADI_INT_RESULT_NOT_ASSERTED	Specified peripheral is not asserting an interrupt.

adi_int_SICSetIVG

Description

This function sets the mapping of a peripheral interrupt source to an IVG level. When called, this function modifies the appropriate system interrupt assignment register(s) of the given peripheral to the specified IVG level. This function does not enable or disable interrupts.

Prototype

```
ADI_INT_RESULT adi_int_SICSetIVG(
        const ADI_INT_PERIPHERAL_ID   PeripheralID,
        const u32                     IVG
);
```

Arguments

`PeripheralID`	`ADI_INT_PERIPHERAL_ID` enumeration value that identifies a peripheral interrupt source
`IVG`	Interrupt vector group assigned to the peripheral

Return Value

The function returns `ADI_INT_RESULT_SUCCESS`, if successful. Other possible return values include:

`ADI_INT_RESULT_INVALID_PERIPHERAL_ID`	Peripheral ID specified is invalid.
`ADI_INT_RESULT_INVALID_IVG`	Interrupt vector group level is invalid.

adi_int_SetIMaskBits

Description

This function is used by the interrupt manager to set bits in the IMASK register. Though it can also be called by the application, the application should not attempt to modify bits in the IMASK register that represent interrupt vector groups that are under the control of the interrupt manager.

The implementation of this function depends upon the operating environment. In the standalone version of the service, this function detects whether the processor is within a protected region of code (refer to the adi_int_EnterCriticalRegion and adi_int_ExitCriticalRegion functions). If it is, the saved value of IMASK is updated accordingly and the current "live" IMASK value is left unchanged. When the outermost adi_int_ExitCriticalRegion function is called, the saved IMASK value with the new bit settings is restored. Upon entering this function, if the processor is not within a protected region of code, the "live" IMASK register is updated accordingly.

Information on the implementation details for this function in other operating environments can be found in the file adi_int_xxx.h, located in the Blackfin/include/services/ directory, where xxx is the operating environment.

Regardless of the implementation details, the API is consistent from environment to operating environment. Application software does not have to change when moving to a different operating environment.

Prototype

```
void adi_int_SetIMASKBits(
        ADI_INT_IMASK      BitsToSet
);
```

Arguments

`BitsToSet`	Replica of the IMASK register containing bits that are to be set in the real IMASK register. A bit with a value of '1' sets the corresponding bit in the IMASK register. A bit with the value of '0' leaves the corresponding bit in the IMASK register unchanged.

Return Value

None

adi_int_SICWakeup

Description

This function configures the system interrupt controller wakeup register to enable or disable the given peripheral interrupt from waking up the core processor.

The `adi_int_SICWakeup` function simply programs the system interrupt controller wakeup register accordingly. The actual servicing of interrupts is not affected by this function.

Prototype

```
ADI_INT_RESULT adi_int_SICWakeup(
        const ADI_INT_PERIPHERAL_ID   PeripheralID,
        u32                           WakeupFlag
);
```

Arguments

`PeripheralID`	`ADI_INT_PERIPHERAL_ID` enumeration value that identifies a peripheral interrupt source
`WakeupFlag`	Enables/disables waking up the core(s) upon triggering of the peripheral interrupt (`TRUE/FALSE`)

Return Value

Return values include:

`ADI_INT_RESULT_SUCCESS`	System interrupt controller has been successfully configured.
`ADI_INT_RESULT_INVALID_PERIPHERAL_ID`	Peripheral ID specified is invalid.

3 POWER MANAGEMENT MODULE

This chapter describes the power management (PM) module that supports dynamic power management of Blackfin processors.

This chapter contains:

Introduction

The power management (PM) module provides access to all aspects of dynamic power management:

- Dynamic switching from one operating mode (full-on, active, sleep, deep sleep, and hibernate) to another
- Dynamic setting of voltage levels and clock frequencies to ensure that an application can be tuned to achieve the best performance while minimizing power consumption
- When coupled with the EBIU module, enables the SDRAM settings to be adjusted upon changes to the system clock to ensure that the best performance is obtained for the complete system. For more information about the EBIU module, see "External Bus Interface Unit Module" on page 4-1.

The module supports two strategies for setting the core and system clock frequencies:

- For a given voltage level, the core clock (`CCLK`) is set to the highest available frequency. The system clock (`SCLK`) is set accordingly.
- For a given combination of core clock and system clock frequencies, the valid values nearest to the chosen ones are used and the voltage level of the processor is adjusted accordingly.

In both cases, validity checks are performed at all stages, ensuring that the processor is not stalled or harmed.

"PM Module Operation – Getting Started" on page 3-3 describes the basic operating stages required to use the power management module.

The power management module uses an unambiguous naming convention to safeguard against conflicts with other software libraries provided by Analog Devices or other companies. To this end, all enumeration values and `typedef` statements use the `ADI_PWR_` prefix, and functions and global variables use the lowercase, `adi_pwr_` equivalent.

Two versions of the library exist for each processor. These correspond to the debug and release configurations in the current VisualDSP++ release. In addition to the usual defaults for the debug configuration, the API functions perform checks on the arguments passed and report appropriate error codes, as required. In the release version of the library, most functions return one of two result codes: `ADI_PWR_RESULT_SUCCESS` on successful completion, or `ADI_PWR_RESULT_NOT_INITIALIZED` when the PM module has not been initialized prior to the function call.

In order to better facilitate the configuration of timing parameters for device drivers, the default unit of frequency for communicating with the power management functions is hertz (Hz) rather than megahertz (MHz). Refer to the `adi_pwr_Init` function (on page 3-24) for more information.

PM Module Operation – Getting Started

The following example illustrates how to use the PM module to configure a 600 MHz ADSP-BF533 processor on an EZ-KIT Lite board to run at the requested core clock and system clock frequencies or to minimize power consumption by pegging the voltage level at 0.95 V.

Step 1:
If used in conjunction with the EBIU controller to adjust SDRAM settings, initialize the EBIU module by calling `adi_ebiu_Init()`. For more information about the EBIU module, see “External Bus Interface Unit Module” on page 4-1.

Step 2:
Initialize the power module by calling `adi_pwr_Init`, passing the parameters for the hardware configuration used. For example, the following code configures the ADSP-BF533 EZ-KIT Lite.

```
ADI_PWR_COMMAND_PAIR power_init_table[] = {
    {
ADI_PWR_CMD_SET_PROC_VARIANT,(void*)ADI_PWR_PROC_BF533SKBC600 },
                    /* 600 MHz ADSP-BF533 variant */
    { ADI_PWR_CMD_SET_PACKAGE,(void*)ADI_PWR_PACKAGE_MBGA },
                    /* in MBGA packaging */
    { ADI_PWR_CMD_SET_VDDEXT, (void*)ADI_PWR_VDDEXT_330 },
                    /* 3.3 V External supplied
                    to voltage regulator */
    { ADI_PWR_CMD_SET_CLKIN,  (void*) 25 },
                    /* 25 MHz clock in */
    { ADI_PWR_CMD_END,        0 }
                    /* no more commands after this */
};
adi_pwr_Init(power_init_table);
```

Step 3:
Decide on the power management strategy to implement. For example, the following code segments demonstrate how to configure the PM module for optimal speed or optimal power consumption.

Optimal Speed
The following statement requests the PM module set the core and system clock frequencies to the maximum values possible.

```
adi_pwr_SetFreq(
        0,               // Core clock frequency (MHz)
        0,               // System clock frequency (MHz)
        ADI_PWR_DF_ON    // Do not adjust the PLL input divider
);
```

Optimal Power Consumption

The following statement requests the PM module set the core and system clock frequencies to the maximum that can be sustained at a voltage level of 0.85 V.

```
adi_pwr_SetMaxFreqForVolt(ADI_PWR_VLEV_085);
```

Dual-Core Considerations

The following sections explain how to use system services with a dual-core configuration.

Using Automatic Synchronization

The PLL programming sequence for a dual-core processor requires that both cores be brought to the IDLE state while changes are applied to the `PLL` and `VR` registers. A dual-core processor may execute a program on each core, or it may execute a program on just one core. When both cores are used to execute a program, a mechanism is required for both cores to go to the IDLE state, and stay there while the registers are written. The power management module provides a mechanism that uses the supplemental interrupt to synchronize the cores for PLL programming. This mechanism is invoked automatically by calling the `adi_pwr_Init()` function on both cores and passing the command `ADI_PWR_CMD_SET_AUTO_SYNC_ENABLED` with a NULL argument, as shown in the following command-pair table for the ADSP-BF561 EZ-KIT Lite.

```
ADI_PWR_COMMAND_PAIR power_init_table[] = {
    {
ADI_PWR_CMD_SET_PROC_VARIANT,(void*)ADI_PWR_PROC_BF561SKBCZ500X
},
                    /* 500 MHz ADSP-BF561 variant */
    { ADI_PWR_CMD_SET_PACKAGE,(void*)ADI_PWR_PACKAGE_MBGA },
                    /* in MBGA packaging */
    { ADI_PWR_CMD_SET_VDDEXT, (void*)ADI_PWR_VDDEXT_330 },
                    /* 3.3 V External supplied
                    to voltage regulator */
    { ADI_PWR_CMD_SET_CLKIN,  (void*) 30 },
                    /* 30 MHz clock in */
    { ADI_PWR_CMD_SET_AUTO_SYNC_ENABLED,  NULL },
                    /* enable auto-synchronization */
    { ADI_PWR_CMD_END,        0 }
                    /* no more commands after this */
};
adi_pwr_Init(power_init_table);
```

Synchronization Requirement

Blackfin dual-core processors are capable of running one core while the other core is idle. Power management and EBIU management require that both cores be placed in the IDLE state when making power management and EBIU controller changes. If the EBIU module has been initialized, and the system clock frequency is changed, the SDRAM timing parameters are automatically adjusted. To avoid corruption of SDRAM, the automatic core synchronization mechanism forces both cores to execute outside of the SDRAM memory space, while the SDRAM timing parameters are updated.

There are two possible operating modes: running on one core, and running applications on both cores.

Running Applications on One Core Only

In this case, one core is used and the other core (core B) is disabled. Upon reset, core B remains disabled until the code running on core A starts core B running, by clearing bit 5 of the SICA_SYSCR register. For example:

```
*pSICA_SYSCR &= 0xFFDF;      // clears bit 5 so Core B
                             // will start running
```

Note that this does not wake core B if it is in the IDLE state. It only allows core B to start executing instructions on startup. To wake core B from IDLE, use one of the two supplemental interrupts (supplemental interrupt 0 is taken over by system services, leaving supplemental interrupt 1 for other uses).

Single-core applications loaded from flash memory or via the SPI port satisfy the above synchronization requirement with no further intervention. However, an emulator session within VisualDSP++ unavoidably wakes up core B. The application developer must return core B to the disabled state to meet the PLL programming requirements. There are two ways to do this. The simplest is to run the following C code on core B:

```
void main() {
    while(1) {
        asm("IDLE;");
    }
}
```

Whenever core B wakes up (due to the PLL programming sequence executed by the power management service) it is immediately returned to the IDLE state.

The other method is to disable the PLL wakeup bit in the `SICB_IWR0` register and go to IDLE. If this is done in the assembler, the following code can take the place of the startup code:

```
#include <defBF561.h>
.section program;

start:
      P0.H = HI(SICB_IWR0); P0.L = LO(SICB_IWR0);
      R0 = 0;
      [P0] = R0;
      IDLE;

.start.end:
.global start;
.type start,STT_FUNC;
```

Running Applications on Both Cores

In this case, both cores execute code. Both cores need to synchronize to ensure that both cores are IDLE and, in some cases, do not execute out of SDRAM as described in the requirement above. There are two choices: 1) define your own synchronization strategy, or 2) use the built-in synchronization provided by the power management module (which must be enabled by a separate command).

To use the built-in synchronization, include the following command value pair to `adi_pwr_Init()` on both cores:

```
{ ADI_PWR_CMD_SET_AUTO_SYNC_ENABLED, NULL }
```

Once activated, the built-in synchronization has exclusive control over supplemental interrupt 0 and chains an appropriate interrupt handler to the appropriate IVG level using the interrupt manager. This prevents the application from using the interrupt for any other synchronization between cores. However, the supplemental interrupt 1 is still available for use outside of system services for other core synchronization purposes.

Additional commands can be used to tailor the synchronization requirements (see Table 3-1.)

Table 3-1. Additional Commands for Tailoring Synchronization

Command	Description
Available on Core A and Core B	
ADI_PWR_CMD_SET_SYNC_LOCK_VARIABLE	Provides the address of an alternative unsigned int lock variable in L2 as an alternative to the built-in lock variable. Not normally needed.
Available on Core B only	
ADI_PWR_CMD_SET_COREB_SUPP_INT0_IVG	Specifies the IVG level assigned to supplemental interrupt 0 on core B. Not normally needed.
ADI_PWR_CMD_SET_FIRST_CLIENT_CALLBACK	Specifies a callback function to be invoked prior to power management changes, for example to pause device drivers.
ADI_PWR_CMD_SET_SECOND_CLIENT_CALLBACK	Specifies a callback function to be invoked subsequent to power management changes, for example to restart device drivers.
ADI_PWR_CMD_SET_CLIENT_HANDLE	Specifies a `void*` value/address which is sent to both the callback functions as the sole argument.

Synchronization Between Cores

Either core can interrupt the other core using a supplemental interrupt. There are two of these on the ADSP-BF561 processor: 0 and 1. A shared lock variable located in L2 memory can send information between the cores as a method of synchronization.

The built-in mechanism requires that core A initiates all power management changes, with core B configured to respond to a supplemental interrupt 0 event, raised by core A. The configuration and handling of this interrupt is managed within the power management module itself. Table 3-2 describes the synchronization sequence.

Table 3-2. Synchronization Sequence Between Cores

Core A	Core B
Raises supplemental interrupt 0, sets the shared adi_pwr_lockvar lock variable, and waits acknowledgement.	Responds to supplemental interrupt 0 by entering interrupt handler.
	Runs first (optional) callback function.
On receiving acknowledgement, performs PLL programming sequence, and configures the SDC accordingly.	Acknowledges interrupt and goes to IDLE.
	Wakes on PLL wakeup and waits for the lock variable to clear.
Completes the process by clearing the lock variable.	Runs second (optional) callback function, and returns from interrupt.

Built-In Lock Variable and Linking Considerations

The lock variable, `adi_pwr_lockvar`, is declared within the file `Blackfin\lib\src\ services\pwr\adi_pwr_lockvar.c` as:

```
section ("l2_shared") testset_t adi_pwr_lockvar = 0;
```

where the memory input section, `l2_shared`, is mapped to the `MEM_L2_SRAM` output section in both the default and generated linker description files (`.ldf`).

According to Appendix A of the *VisualDSP++ 5.0 C/C++ Compiler and Library Manual for Blackfin Processors*, there are two possible approaches for building applications that run across both cores.

- One application per core, where executables are built for each core using two passes of the linker
- One application across both cores, where a five-project group is used and a single linker pass builds executables for both processors

The latter approach maps the lock variable to L2 memory shared by both processors without any user intervention. The "one application per core" approach requires user intervention to ensure that the lock variable is mapped to the same address in L2 memory in each of the executables. This is achieved by using the `RESOLVE` statement in the `.ldf` file, which can be used to resolve a symbol to its memory location assigned in the executable for the other core.

The default and generated `.ldf` files for core B contain the following:

```
   /* $VDSG<customise-shared-symbols>                       */
   /* This code is preserved if the LDF is re-generated.    */

////////////////////////////////////////////////////////////
   // ldf_shared_symbols

   /* Issue resolve statement for shared symbols mapped in CoreA.
   ** Below is an example of how to do that.
   */
#if defined(OTHERCORE)  /* OTHERCORE is a macro defined to name
                           of the CoreA DXE */
#  include <shared_symbols.h> /* C runtime library
                                 shared symbols,
                                 ** uses macro OTHERCORE.
                                */
```

```
#if 0
                    /* example resolve for user shared data*/
   RESOLVE(_a_shared_datum, OTHERCORE)
#endif

#endif /* OTHERCORE */

   /* $VDSG<customise-shared-symbols>                        */
```

The `shared_symbols.h` header file contains the `RESOLVE` statements for the C/C++ libraries' shared symbols and includes the additional header file, `services/services_shared_symbols.h`, containing the `RESOLVE` statements for the system services shared symbols. Currently, the `adi_pwr_lockvar` variable is the only shared symbol required by system services.

All that is required is to define `OTHERCORE` within the user-modifiable block ahead of where it is tested (or by setting its value through the **Link:LDF Preprocessing** page of the **Project Options** dialog box within VisualDSP++). For example, if the executable, `CoreA.dxe` (say), for core A is in the Release subdirectory of a directory, CoreA, adjacent to the CoreB project directory, you need to define `OTHERCORE` as `..\CoreA\Release\CoreA.dxe`. For example:

```
#define OTHERCORE ..\CoreA\Release\CoreA.dxe
#if defined(OTHERCORE)
:
```

Refer to Appendix A of the *VisualDSP++ 5.0 C/C++ Compiler and Library Manual for Blackfin Processors* and the *VisualDSP++ 5.0 Linker and Utilities Manual* for details.

SDRAM Initialization Prior to Loading an Executable

Applications that require code (and/or data) to be located in SDRAM at load time require the SDRAM controller to be initialized beforehand. This is the case for all applications where instruction and/or data caching are enabled. However, the EBIU service's initialization routine, `adi_ebiu_Init()`, is not executed until after the application has loaded.

There are two ways to load an application into the processor core:

- Through an emulator session connected to the VisualDSP++ IDDE
- From flash memory or a device attached to the SPI port when the processor is reset

In the first case, it is imperative that the **Use XML reset values** option is selected in the **Target Options** dialog box (available through the **Settings** menu). This ensures that the SDRAM is correctly (if not optimally) configured prior to the application loading. Once loaded, the application's use of the power management services and EBIU services ensures that the SDRAM is optimally configured.

When the application is not loaded from within an emulator session, it is necessary for the boot loader to initialize SDRAM prior to loading the application. This is achieved by using an initialization block as described in the *VisualDSP++ 5.0 Loader and Utilities* manual, where the example given demonstrates the initialization of SDRAM.

This initialization block code is compiled into an executable and is passed to the loader via the `-init` filename option or in the **Initialization file** field of the **Load:Options** page of the **Project Options** dialog box. A separate project is thus required for the initialization block. An example initialization block project is provided in the relevant directory (for the processor) under the `Blackfin\ldr\init_code` directory of the

VisualDSP++ installation. The values required for the SDRAM configuration registers can be set to the ones used in the relevant `.xml` file for the processor, for example `ADSP-BF533-proc.xml`, located in the `System\ArchDef` directory of the VisualDSP++ installation.

When a different memory configuration is required (other than the one supplied with the EZ-KIT Lite evaluation systems), the user is required to work out the appropriate values. When loading a program from the IDDE, either use the Custom Board Support feature, now available with VisualDSP++5.0 (described in `Help\Graphical Environment\Custom Board Support`), or simply change the values at the bottom of the relevant `.xml` file after backing up the original file.

Power Management API Reference

This section provides descriptions of the PM module's application programming interface (API) functions.

Notation Conventions

The reference pages for the API functions use the following format:

Name – Name and purpose of the function

Description – Function specification

Prototype – Required header file and functional prototype

Arguments – Description of function arguments

Return Value – Description of function return values

adi_pwr_AdjustFreq

Description

This function allows the core and system clocks to be modified by specifying the core and system clock divider ratios, CSEL and SSEL, in the PLL_DIV register. The processor is not idled.

Prototype

```
ADI_PWR_RESULT adi_pwr_AdjustFreq(
          const ADI_PWR_CSEL csel,
          const ADI_PWR_SSEL ssel
);
```

Arguments

csel	ADI_PWR_CSEL value specifies how the voltage core oscillator (VCO) frequency is divided to obtain a new core clock frequency. The divider value cannot exceed the ssel value. See "ADI_PWR_CSEL" on page 3-47.
ssel	ADI_PWR_SSEL value specifies how the VCO frequency is divided to obtain a new system clock frequency. See "ADI_PWR_SSEL" on page 3-52.

Return Value

In the debug variant of the library, the function adi_pwr_AdjustFreq returns one of the following result codes; otherwise, the function returns ADI_PWR_RESULT_SUCCESS.

ADI_PWR_RESULT_SUCCESS	Process completed successfully.
ADI_PWR_RESULT_NOT_INITIALIZED	PM module has not been initialized.
ADI_PWR_RESULT_INVALID_CSEL	Invalid value for CSEL has been specified.

ADI_PWR_RESULT_INVALID_SSEL	Invalid value for SSEL has been specified.
ADI_PWR_INVALID_CSEL_SSEL_COMBINATION	Core clock divider is greater than the system clock divider value, or both ADI_PWR_CSEL_NONE and ADI_PWR_SSEL_NONE are specified.

adi_pwr_Control

Description

This function enables the dynamic power management registers to be configured or queried according to command-value pairs ("ADI_PWR_COMMAND_PAIR" on page 3-47), specified in one of three ways:

1.) A single command-value pair is passed.

```
adi_pwr_Control(
     ADI_PWR_CMD_SET_INPUT_DELAY,
     (void*)ADI_PWR_INPUT_DELAY_ENABLE,
);
```

2.) A single command-value pair structure is passed.

```
ADI_PWR_COMMAND_PAIR cmd = {
    ADI_PWR_CMD_SET_INPUT_DELAY,
    (void*)ADI_PWR_INPUT_DELAY_ENABLE,
};
adi_pwr_Control(ADI_PWR_CMD_PAIR,(void*)&cmd);
```

3.) A table of `ADI_PWR_COMMAND_PAIR` structures is passed. The last entry in the table must be `ADI_PWR_CMD_END`.

```
ADI_PWR_COMMAND_PAIR table[] = {
    { ADI_PWR_CMD_SET_INPUT_DELAY,
(void*)ADI_PWR_INPUT_DELAY_ENABLE
    { ADI_PWR_CMD_SET_OUTPUT_DELAY,
(void*)ADI_PWR_OUTPUT_DELAY_ENABLE
    { ADI_PWR_CMD_END, 0}
};
adi_pwr_Control(
         ADI_PWR_CMD_TABLE,
```

```
            (void*)table
    );
```

Refer to “ADI_PWR_COMMAND” on page 3-42 and “Public Data Types and Enumerations” on page 3-42 for the complete list of commands and associated values.

Prototype

```
ADI_PWR_RESULT adi_pwr_Control(
         ADI_PWR_COMMAND command,
         void *Value
);
```

Arguments

Command	ADI_PWR_COMMAND enumeration value specifies the meaning of the associated value argument.
Value	This is the required value. See “ADI_PWR_COMMAND” on page 3-42.

Return Value

In debug mode, the adi_pwr_Control function returns one of the following values; otherwise, ADI_PWR_RESULT_SUCCESS is returned.

ADI_PWR_RESULT_SUCCESS	Function completed successfully.
ADI_PWR_RESULT_BAD_COMMAND	Invalid command has been specified.
ADI_PWR_RESULT_NOT_INITIALIZED	PM module has not been initialized.
ADI_PWR_RESULT_INVALID_INPUT_DELAY	Input delay value is invalid.
ADI_PWR_RESULT_INVALID_OUTPUT_DELAY	Output delay value is invalid.
ADI_PWR_RESULT_INVALID_LOCKCNT	PLL lock count value is invalid.

adi_pwr_GetConfigSize

Description

This function returns the number of bytes required to save the current configuration data. This value is also available via the ADI_PWR_SIZEOF_CONFIG macro.

The return values of adi_pwr_GetConfigSize and the macro, ADI_PWR_SIZEOF_CONFIG, incorporate the size of the EBIU module configuration, regardless whether the latter is initialized.

Prototype

```
size_t adi_pwr_GetConfigSize(void);
```

Return Value

The size of the configuration structure.

adi_pwr_GetFreq

Description

This function returns the current values of the CCLK, SCLK, and voltage core oscillator (VCO) frequencies.

Prototype

```
ADI_PWR_RESULT adi_pwr_GetFreq(
        u32 *fcclk,
        u32 *fsclk,
        u32 *fvco);
```

Arguments

fcclk	Address of location to store the current CCLK value (Hz)
fsclk	Address of location to store the current SCLK value (Hz)
fvco	Address of location to store the VCO frequency (Hz)

Return Value

In the debug variant of the library, the function adi_pwr_GetFreq returns one of the following result codes; otherwise, the function returns ADI_PWR_RESULT_SUCCESS.

ADI_PWR_RESULT_SUCCESS	Process completed successfully.
ADI_PWR_RESULT_NOT_INITIALIZED	PM module has not been initialized.

adi_pwr_GetPowerMode

Description

This function returns the current power mode of the processor (only applicable for full-on and active modes).

Prototype

```
ADI_PWR_MODE adi_pwr_GetPowerMode(void);
```

Return Value

The current power mode as an `ADI_PWR_MODE` value.

adi_pwr_GetPowerSaving

Description

This function calculates the power saving value for the current PLL and voltage regulator settings, as per the data sheet formulas with the time ratio set to `unity`, and the nominal values as per the maximum possible (that is, `at VLEV = 1.3 V`).

Prototype

```
u32 adi_pwr_GetPowerSaving(void);
```

Return Value

The percentage power saving value.

adi_pwr_Init

Description

This function initializes the power management module. The following values must be set for successful initialization:

Processor variant	ADI_PWR_PROC_KIND value describes the processor variant. See "ADI_PWR_PROC_KIND" on page 3-50.
Package kind	ADI_PWR_PACKAGE_KIND value describes the packaging type of the processor. See "ADI_PWR_PACKAGE_KIND" on page 3-49.
Core voltage (V_{DDINT})	ADI_PWR_VLEV value specifying the internal voltage, applied to the core by an external voltage regulator. The internal voltage regulator is bypassed. Its absence in the command table implies that the internal regulator is to be used. An external voltage regulator is required for the ADSP-BF533SKBC750 processor, as the internal voltage regulator cannot supply the 1.4 V required for the processor to run at 750 MHz.
External voltage (V_{DDEXT})	ADI_PWR_VDDEXT value specifies the external voltage supplied to the voltage regulator. This value, when coupled with the packaging, determines the maximum system clock (SCLK) frequency available. See "ADI_PWR_VDDEXT" on page 3-53.
CLKIN	Frequency of the external clock oscillator supplied to the processor in either MHz or Hz.

These are communicated to the adi_pwr_Init function by passing a pointer to a table of command-value pairs, terminated with the ADI_PWR_CMD_END command.

For example, the following ADI_PWR_COMMAND_PAIR table gives the EZ-KIT Lite values:

```
ADI_PWR_COMMAND_PAIR ezkit_init[] = {
    { ADI_PWR_CMD_SET_PROC_VARIANT, ADI_PWR_PROC_BF533SKBC600 },
    { ADI_PWR_CMD_SET_PACKAGE,   ADI_PWR_PACKAGE_MBGA },
    { ADI_PWR_CMD_SET_VDDEXT,   ADI_PWR_VDDEXT_330 },
    { ADI_PWR_CMD_SET_CLKIN,    25 /* MHz */ },
```

```
    { ADI_PWR_CMD_END,          0 }
};
```

Table 3-3 lists valid command-value pairs.

Table 3-3. adi_pwr_Init Command-Value Pairs

Command	Description
ADI_PWR_CMD_SET_CCLK_TABLE	Address of a table containing ADI_PWR_NUM_VLEVS values of type u16 detailing the maximum CCLK frequency for each ADI_PWR_VLEV value. These values are used instead of the data sheet values.
ADI_PWR_CMD_SET_PROC_VARIANT	ADI_PWR_PROC_KIND value specifies the processor variant (mandatory). See "ADI_PWR_PROC_KIND" on page 3-50.
ADI_PWR_CMD_SET_PACKAGE	ADI_PWR_PACKAGE_KIND value describes the packaging type of the processor (mandatory). See "ADI_PWR_PROC_KIND" on page 3-50.
ADI_PWR_CMD_SET_CLKIN	u16 value specifies the external clock frequency, CLKIN, supplied to the processor (mandatory).
ADI_PWR_CMD_SET_VDDINT	ADI_PWR_VLEV value specifies the core voltage level. This should only be passed to adi_pwr_Init if an external voltage regulator is used, as its presence instructs the module to bypass the internal regulator. See "ADI_PWR_VLEV" on page 3-53.
ADI_PWR_CMD_SET_VDDEXT	ADI_PWR_VDDEXT value specifies the external voltage level applied to the internal voltage regulator (mandatory). See "ADI_PWR_VDDEXT" on page 3-53.
ADI_PWR_CMD_SET_IVG	interrupt_kind value (see exception.h) specifies the IVG level for the PLL_WAKEUP event.

Table 3-3. adi_pwr_Init Command-Value Pairs (Cont'd)

Command	Description
ADI_PWR_CMD_SET_INPUT_DELAY	ADI_PWR_INPUT_DELAY value specifies whether to add approximately 200 ps of delay to the time when inputs are latched on the external memory interface. See "ADI_PWR_INPUT_DELAY" on page 3-48.
ADI_PWR_CMD_SET_OUTPUT_DELAY	ADI_PWR_OUTPUT_DELAY value specifies whether to add approximately 200 ps of delay to external memory output signals. See "ADI_PWR_OUTPUT_DELAY" on page 3-48.

The adi_pwr_Init function can only be called once. Subsequent calls to adi_pwr_Init are ignored with the ADI_PWR_RESULT_ALREADY_INITIALIZED result code returned.

Table 3-4 lists valid command-value pairs for an ADSP-BF561 dual-core processor.

Table 3-4. ADSP-BF561 Dual-Core Processor Command-Value Pairs

Command	Description
Commands relevant to ADSP-BF561 dual-core processor only.	
ADI_PWR_CMD_SET_AUTO_SYNC_ENABLED	Instructs the power management module to use its built-in mechanism for synchronizing the cores across changes to the PLL. Use NULL as the associated value. This command is to be passed to adi_pwr_Init() on both cores.
ADI_PWR_CMD_SET_COREB_SUPP_INT0_IVG	IVG level that is assigned to supplemental interrupt 0 on core B. This command is passed to adi_pwr_Init() on core B only.

Table 3-4. ADSP-BF561 Dual-Core Processor Command-Value Pairs (Cont'd)

Command	Description
ADI_PWR_CMD_SET_SYNC_LOCK_VARIABLE	Address of a lock variable in L2 that is used for built-in synchronization. The default is to use the built-in, adi_pwr_lockvar, variable.
ADI_PWR_CMD_SET_FIRST_CLIENT_CALLBACK	Address of a function called by core B before PLL changes are made. This command is passed to adi_pwr_Init() on core B only.
ADI_PWR_CMD_SET_SECOND_CLIENT_CALLBACK	Address of a function called by core B after PLL changes are made. This command is passed to adi_pwr_Init() on core B only.
ADI_PWR_CMD_SET_CLIENT_HANDLE	void* value/address that is sent to the callback functions. This command is passed to adi_pwr_Init() on core B only.

Prototype

```
ADI_EBIU_RESULT adi_pwr_Init(
        ADI_PWR_COMMAND_PAIR *table
);
```

Arguments

`ConfigData`	Address of a table of command-value pairs as defined by "ADI_PWR_COMMAND_PAIR" on page 3-47 and "Public Data Types and Enumerations" on page 3-42. The last command in the table must be the `ADI_EBIU_CMD_END` command.

Return Value

In the debug variant of the library, `adi_pwr_Init` returns the results codes listed below. Otherwise, the value of `ADI_PWR_RESULT_SUCCESS` is returned, or the value of `ADI_PWR_RESULT_ALREADY_INITIALIZED` is returned when the PM module is already initialized.

In order to better facilitate the configuration of timing parameters for device drivers, the default unit of frequency for communicating with the power management functions is hertz (Hz) rather than megahertz (MHz).

Should the application require MHz rather than Hz, the power management service can be commanded to use MHz by passing the new command `ADI_PWR_CMD_SET_FREQ_AS_MHZ` to the `adi_pwr_Init()` function. The companion value parameter is ignored with this command. For example, if passing a table of commands to the `adi_pwr_Init()` function, the following command should be added to the table:

```
{ ADI_PWR_CMD_SET_FREQ_AS_MHZ, NULL },
```

Table 3-5 lists and explains the return codes.

Table 3-5. adi_pwr_Init Return Codes

Return Value	Explanation
ADI_PWR_RESULT_SUCCESS	Function completed successfully.
ADI_PWR_RESULT_BAD_COMMAND	Invalid command has been specified.
ADI_PWR_RESULT_ALREADY_INITIALIZED	Module has already been initialized.
ADI_PWR_RESULT_INVALID_VLEV	Invalid core voltage level has been specified.
ADI_PWR_RESULT_INVALID_VDDEXT	Invalid external voltage level has been specified.
ADI_PWR_RESULT_INVALID_PROCESSOR	Processor type specified is invalid.
ADI_PWR_RESULT_INVALID_IVG	IVG level supplied is invalid.
ADI_PWR_RESULT_INVALID_INPUT_DELAY	Input delay value is invalid.
ADI_PWR_RESULT_INVALID_OUTPUT_DELAY	Output delay value is invalid.
ADI_PWR_RESULT_INVALID_LOCKCNT	PLL lock count value is invalid.
ADI_PWR_RESULT_INVALID_EZKIT	Invalid EZ-KIT Lite type specified.

adi_pwr_LoadConfig

Description

This function restores the current configuration values from the memory location pointed to by the `hConfig` argument. The PLL controller and voltage regulator are reprogrammed. If the EBIU module is initialized, its configuration is also loaded and the SDRAM controller is programmed.

Prototype

```
ADI_PWR_RESULT adi_pwr_LoadConfig(
        const ADI_PWR_CONFIG_HANDLE hConfig,
        const size_t szConfig
);
```

Arguments

`hConfig`	Address of the memory area where the current configuration is restored
`szConfig`	Number of bytes available at the given address. This value must be greater than or equal to the `adi_pwr_GetConfigSize()` return value.

Return Value

In the debug variant of the library, `adi_pwr_Init` returns the following results codes; otherwise, the value of `ADI_PWR_RESULT_SUCCESS` is returned.

`ADI_PWR_RESULT_SUCCESS`	Function completed successfully.
`ADI_PWR_RESULT_NO_MEMORY`	Value of `szConfig` is insufficient.
`ADI_PWR_RESULT_FAILED`	Address of `hConfig` is zero.
`ADI_PWR_RESULT_NOT_INITIALIZED`	PM module has not been initialized.

adi_pwr_Reset

Description

This function resets the PLL controller to its hardware reset values.

Prototype

```
void adi_pwr_Reset(void);
```

Arguments

None

Return Value

None

adi_pwr_SaveConfig

Description

This function stores the current configuration values into the memory area pointed to by the hConfig argument. If the EBIU module is initialized, its configuration is also saved; otherwise, the appropriate fields are undefined.

Prototype

```
ADI_PWR_RESULT adi_pwr_SaveConfig(
        const ADI_PWR_CONFIG_HANDLE hConfig,
        const size_t szConfig
);
```

Arguments

hConfig	Address of the memory locatioin where the current configuration is restored
szConfig	Number of bytes available at the given address. The value must be greater than or equal to the adi_pwr_GetConfigSize() return value.

Return Value

In the debug variant of the library, adi_pwr_Init returns the following results codes, otherwise, the value of ADI_PWR_RESULT_SUCCESS is returned.

ADI_PWR_RESULT_SUCCESS	Function completed successfully.
ADI_PWR_RESULT_NO_MEMORY	Value of szConfig is insufficient.
ADI_PWR_RESULT_FAILED	Address of hConfig is zero.
ADI_PWR_RESULT_NOT_INITIALIZED	PM module has not been initialized.

adi_pwr_SetFreq

Description

This function sets the PLL controller to provide CCLK and SCLK values as close as possible to the requested values (in Hz). If the voltage regulator is not disabled, it is adjusted (where necessary) to provide the minimum voltage that can sustain the requested frequencies.

The processor is idled to affect the changes.

> This function always finds a solution where the CSEL divider in the PLL_DIV register is unity. If the PLL input divider is requested, the difference between the requested and obtained values is minimized.

To determine the values set by this function, use adi_pwr_GetFreq.

Prototype

```
ADI_PWR_RESULT adi_pwr_SetFreq(
          const u32 fcclk,
          const u32 fsclk,
          const ADI_PWR_DF df);
```

Arguments

fcclk	Requested CCLK value in Hz. If this is set to zero, the adi_pwr_SetFreq function gives priority to matching the given SCLK frequency and calculates and sets a CCLK frequency as close as possible to the maximum possible for the current voltage level.
fsclk	Requested SCLK value in Hz
df	The ADI_PWR_DF enumeration (see “ADI_PWR_DF” on page 3-48) is used in this case to indicate whether this function should enable the PLL input divider, to minimize the difference between the requested clock frequency and the actual frequency that can be obtained. Enabling it can also lead to lower power dissipation. Passing ADI_PWR_DF_ON indicates that the PLL input divider has already been enabled. Passing ADI_PWR_DF_NONE indicates that the function may enable it to achieve better granularity. (ADI_PWR_DF_OFF has no meaning in this context.)

Return Value

In the debug variant of the library, the adi_pwr_SetFreq function returns one of the following result codes, otherwise, it returns ADI_PWR_RESULT_SUCCESS.

ADI_PWR_RESULT_SUCCESS	Process completed successfully.
ADI_PWR_RESULT_NOT_INITIALIZED	PM module has not been initialized.

adi_pwr_SetMaxFreqForVolt

Description

This function sets the voltage regulator control register, VR_CTL, with the required voltage level and adjusts the processor's CCLK and SCLK values to the maximum sustainable level.

The processor is idled to affect the changes.

Prototype

```
ADI_PWR_RESULT adi_pwr_SetMaxFreqForVolt(
        const ADI_PWR_VLEV vlev
);
```

Arguments

vlev	Required voltage level is set as an ADI_PWR_VLEV enumeration value. See "ADI_PWR_VLEV" on page 3-53.

Return Value

In debug variant of the library, the adi_pwr_SetMaxFreqForVolt function returns the following result codes; otherwise, ADI_PWR_RESULT_SUCCESS is returned.

ADI_PWR_RESULT_INVALID_VR_VLEV	vlev value is invalid.
ADI_PWR_RESULT_VR_BYPASSED	Voltage regulator is bypassed. A call to adi_dma_SetVoltageRegulator with a non-zero switching frequency value is required prior to this call. See "adi_pwr_SetVoltageRegulator" on page 3-38.
ADI_PWR_RESULT_NOT_INITIALIZED	PM module has not been initialized.

adi_pwr_SetPowerMode

Description

This function sets the power mode of the processor. There are five modes:

- **Full-On**. The processor core clock (`CCLK`) and system clock (`SCLK`) run at the frequencies set via the `adi_pwr_SetFreq` or `adi_pwr_SetVoltageRegulator` functions. Full DMA is enabled.
- **Active.** The PLL is bypassed so that the processor core clock and system clock run at the `CLKIN` input clock frequency. DMA access is available to configured L1 memories appropriately.
- **Sleep**. The core processor is idled. The system clock continues to run at the speed set via the `adi_pwr_SetFreq` or `adi_pwr_SetVoltageRegulator` functions. DMA is restricted to external memory.
- **Deep Sleep**. The processor core and all peripherals, except the real-time clock (RTC), are disabled. DMA is not supported in this mode.

  SDRAM is set to self-refresh mode. The voltage regulator is powered up on RTC interrupt or a hardware reset event. In both cases, the core reset sequence is initiated.
- **Hibernate**. The internal voltage regulator is powered down. SDRAM is set to self-refresh mode. The voltage regulator is powered up on hardware reset.

Until SDRAM is properly configured and the refresh rate is appropriate, data held in SDRAM will decay. This only applies to exiting hibernate or deep sleep mode by a hardware reset event. For ADSP-BF531, ADSP-BF532, and ADSP-BF533 processor cores, the `SCKE` pin on the processor is asserted on reset, causing the SDRAM to exit self-refresh mode. This behavior is a constraint of

PC-133 compliance. For some processors, currently including the ADSP-BF537 family and the ADSP-BF527 family, this restriction can be circumvented by enabling the `CKELOW` bit in the `VR_CTL` register (see "adi_pwr_SetVoltageRegulator" on page 3-38). This can also be achieved by inserting the following command-value pair to the table that is passed to the `adi_pwr_Init` function:

```
{ ADI_PWR_CMD_SET_PC133_COMPLIANCE, 0 }
```

Prototype

```
ADI_PWR_RESULT adi_pwr_SetPowerMode(
        const ADI_PWR_MODE mode);
```

Arguments

`mode`	`ADI_PWR_MODE` value indicates the state the processor is transitioned to. See "ADI_PWR_MODE" on page 3-49.

Return Value

In the debug variant of the library, the function `adi_pwr_SetPowerMode` returns one of the following result codes; otherwise, the function returns `ADI_PWR_RESULT_SUCCESS`.

`ADI_PWR_RESULT_SUCCESS`	Process completed successfully.
`ADI_PWR_RESULT_NOT_INITIALIZED`	PM module has not been initialized.
`ADI_PWR_RESULT_INVALID_MODE`	Either an incorrect mode has been requested or the requested mode cannot be reached from the current mode.

adi_pwr_SetVoltageRegulator

Description

This function sets the voltage regulator control register, VR_CTL, with one or more of the following fields.

VLEV	Required voltage level as an ADI_PWR_VLEV enumeration value. See “ADI_PWR_VLEV” on page 3-53.
FREQ	Required voltage regulator switching oscillator frequency as an ADI_PWR_VR_FREQ enumeration value. See “ADI_PWR_VR_FREQ” on page 3-55. Note: supply ADI_PWR_VR_FREQ_POWERDOWN to bypass the on-board voltage regulator.
GAIN	Required gain value as an ADI_PWR_VR_GAIN enumeration value. See “ADI_PWR_VR_GAIN” on page 3-55.
WAKE	ADI_PWR_VR_WAKE enumeration value indicating whether the voltage regulator can be awakened from power-down upon an interrupt from the real-time clock or a low-going edge on the RESET# pin. See “ADI_PWR_VR_WAKE” on page 3-56.
PHYWE	ADI_PWR_VR_PHYWE enumeration value indicating whether the voltage regulator can be awakened from power down by activity on the Ethernet PHY. See “ADI_PWR_VR_PHYWE” on page 3-56.
CANWE	ADI_PWR_VR_CANWE enumeration value indicating whether the voltage regulator can be awakened from power down by activity on the CAN bus. See “ADI_PWR_VR_CANWE” on page 3-54.
CLKBUFOE	ADI_PWR_VR_CLKBUFOE enumeration value to govern whether other devices, most likely the Ethernet PHY, are clocked by the input clock, CLKIN. This bit is set if the Ethernet PHY is used on the ADSP-BF537 EZ-KIT Lite board. See “ADI_PWR_VR_CLKBUFOE” on page 3-55.
CKELOW	ADI_PWR_VR_CKELOW enumeration value to govern whether to protect against the default reset state behavior of setting the EBIU pins to their inactive state. This bit is set if the SDRAM is placed into self-refresh mode while the processor is in hibernate state. See “ADI_PWR_VR_CKELOW” on page 3-54.
USBWE	ADI_PWR_VR_USBWE enumeration value indicating whether the voltage regulator can be awakened from power-down by activity on the USB interface. See “ADI_PWR_VR_USBWE” on page 3-54.

These values are communicated to the adi_pwr_SetVoltageRegulator function by passing a single command-value pair or a sequence of pairs in a table terminated with the ADI_PWR_CMD_END command in the same way as for the adi_pwr_Control function. For more detailed information, refer to "adi_pwr_Control" on page 3-18.

For example, to bypass the built-in voltage regulator, the following code could be used.

```
adi_pwr_SetVoltageRegulator(ADI_PWR_SET_VR_FREQ,
        (void*) ADI_PWR_VR_FREQ_POWERDOWN);
```

The following table defines the command-value pairs that can be used with the adi_pwr_SetVoltageRegulator function. Use of any other pairs is invalid.

Command	Associated Data Value
ADI_PWR_CMD_END	Data value is ignored as the command simply marks the end of a table of command pairs.
ADI_PWR_CMD_PAIR	Used to tell adi_pwr_SetVoltageRegulator that a single command pair is being passed.
ADI_PWR_CMD_TABLE	Used to tell adi_pwr_SetVoltageRegulator that a table of command pairs is being passed.
ADI_PWR_CMD_SET_VR_VLEV	ADI_PWR_VLEV value specifying the voltage level required of the voltage regulator. See "ADI_PWR_VLEV" on page 3-53.
ADI_PWR_CMD_SET_VR_FREQ	ADI_PWR_VR_FREQ value specifying the required voltage regulator switching oscillator frequency. See "ADI_PWR_VR_FREQ" on page 3-55. Use the ADI_PWR_VR_FREQ_POWERDOWN value to bypass the on-board voltage regulator.
ADI_PWR_CMD_SET_VR_GAIN	ADI_PWR_VR_GAIN value specifying the internal loop gain of the switching regulator loop. See "ADI_PWR_VR_GAIN" on page 3-55.

ADI_PWR_CMD_SET_VR_WAKE	ADI_PWR_VR_WAKE value indicating whether to enable/disable the WAKE bit. See "ADI_PWR_VR_WAKE" on page 3-56.
ADI_PWR_CMD_SET_VR_PHYWE	ADI_PWR_VR_PHYWE enumeration value indicating whether to enable/disable the PHYWE bit. See "ADI_PWR_VR_PHYWE" on page 3-56.
ADI_PWR_CMD_SET_VR_CANWE	ADI_PWR_VR_CANWE enumeration value indicating whether to enable/disable the CANWE bit. See "ADI_PWR_VR_CANWE" on page 3-54.
ADI_PWR_CMD_SET_VR_CLKBUFOE	ADI_PWR_VR_CLKBUFOE enumeration value indicating to enable/disable the CLKBUFOE bit. See "ADI_PWR_VR_CLKBUFOE" on page 3-55.
ADI_PWR_CMD_SET_VR_CKELOW	ADI_PWR_VR_CKELOW enumeration value indicating whether to enable/disable the CKELOW bit. See "ADI_PWR_VR_CKELOW" on page 3-54.
ADI_PWR_CMD_SET_VR_USBWE	ADI_PWR_VR_USBWE enumeration value indicating whether to enable/disable the USB wakeup bit. See "ADI_PWR_VR_USBWE" on page 3-54.

The processor's CCLK and SCLK frequencies are not adjusted. When necessary, the processor is idled to effect the changes. If the requested voltage level is insufficient to sustain the current frequency values, the function returns an error without amending any settings.

Prototype

```
ADI_PWR_RESULT adi_pwr_SetVoltageRegulator(
        ADI_PWR_COMMAND command,
        void *Value
);
```

Arguments

Command	ADI_PWR_COMMAND enumeration value specifies the meaning of the associated value argument
Value	This is the required value. See "adi_pwr_SetVoltageRegulator" on page 3-38.

Return Value

In debug variant of the library, the adi_pwr_SetVoltageRegulator function returns the following result codes; otherwise, ADI_PWR_RESULT_SUCCESS is returned.

ADI_PWR_RESULT_INVALID_VR_VLEV	VLEV argument is invalid or insufficient to sustain the current core and system clock frequencies.
ADI_PWR_RESULT__INVALID_VR_FREQ	FREQ value is invalid.
ADI_PWR_RESULT__INVALID_VR_GAIN	GAIN value is invalid.
ADI_PWR_RESULT__INVALID_VR_WAKE	WAKE value is invalid.
ADI_PWR_RESULT_INVALID_VR_PHYWE	PHYWE value is invalid.
ADI_PWR_RESULT_INVALID_VR_CANWE	CANWE value is invalid.
ADI_PWR_RESULT_INVALID_VR_CLKBUFOE	CLKBUFOE value is invalid.
ADI_PWR_RESULT_INVALID_VR_CKELOW	CKELOW value is invalid.
ADI_PWR_RESULT_INVALID_VR_USBWE	USB wakeup value is invalid.
ADI_PWR_RESULT__BAD_COMMAND	Command argument is unrecognized.
ADI_PWR_RESULT_NOT_INITIALIZED	PM module has not been initialized.

Public Data Types and Enumerations

This section provides descriptions of the PM public data types and enumerations.

ADI_PWR_COMMAND

The ADI_PWR_COMMAND enumeration type describes the command type in an ADI_PWR_COMMAND_PAIR structure. Table 3-6 details the available commands, the associated data values, and the valid context for their use.

Table 3-6. ADI_PWR_COMMAND Available Commands

Command	Associated Data Value
Commands that can be used with the adi_pwr_Init, adi_pwr_Control, and adi_pwr_SetVoltageRegulator functions	
ADI_PWR_CMD_END	Data value is ignored as the command simply marks the end of a table of command pairs.
Commands that can be used with either the adi_pwr_Control or adi_pwr_SetVoltageRegulator functions	
ADI_PWR_CMD_PAIR	Indicates that a single command pair is being passed.
ADI_PWR_CMD_TABLE	Indicates that a table of command pairs is being passed.
Commands that can be used with either the adi_pwr_Init or adi_pwr_Control functions	
ADI_PWR_CMD_SET_INPUT_DELAY	ADI_PWR_INPUT_DELAY value specifying whether to add approximately 200 ps of delay to the time when inputs are latched on the external memory interface. See “ADI_PWR_INPUT_DELAY” on page 3-48.
ADI_PWR_CMD_SET_OUTPUT_DELAY	ADI_PWR_OUTPUT_DELAY value specifying whether to add approximately 200 ps of delay to external memory output signals. See “ADI_PWR_OUTPUT_DELAY” on page 3-48.

Table 3-6. ADI_PWR_COMMAND Available Commands (Cont'd)

Command	Associated Data Value
ADI_PWR_CMD_SET_PLL_LOCKCNT	u16 value specifying the number of SCLK cycles to occur during the IDLE stage of the PLL programming sequence before the processor sets the PLL_LOCKED bit in the PLL_STAT register. This value is held in the PLL_LOCKCNT register.
Commands valid only when passed to the adi_pwr_Init function.	
ADI_PWR_CMD_SET_PROC_VARIANT	ADI_PWR_PROC_KIND value specifying the processor variant. See "ADI_PWR_PROC_KIND" on page 3-50.
ADI_PWR_CMD_SET_PACKAGE	ADI_PWR_PACKAGE_KIND value describing the packaging type of the processor. See "ADI_PWR_PACKAGE_KIND" on page 3-49.
ADI_PWR_CMD_SET_CLKIN	u16 value specifying the external clock frequency, CLKIN, supplied to the processor in either MHz or Hz.
ADI_PWR_CMD_SET_VDDINT	ADI_PWR_VLEV value specifying the core voltage level provided by an external voltage regulator. See "ADI_PWR_VLEV" on page 3-53.
ADI_PWR_CMD_SET_VDDEXT	ADI_PWR_VDDEXT value specifying the external voltage level applied to the internal voltage regulator. See "ADI_PWR_VDDEXT" on page 3-53)
ADI_PWR_CMD_FORCE_DATASHEET_VALUES	Enforces the core clock frequency limits for each voltage level as defined in the relevant data sheet (default).
ADI_PWR_CMD_SET_CCLK_TABLE	Address of a table containing ADI_PWR_NUM_VLEVS values of type u16 detailing the max CCLK frequency for each ADI_PWR_VLEV value. These values are used instead of the data sheet values.
ADI_PWR_CMD_SET_IVG	u16 value specifying the IVG level for the PLL_WAKEUP event. This defaults to 7.

Table 3-6. ADI_PWR_COMMAND Available Commands (Cont'd)

Command	Associated Data Value
ADI_PWR_CMD_SET_PC133_COMPLIANCE	ADI_PWR_PC133_COMPLIANCE value specifying whether the SDRAM is to comply with the PC-133 standard. Non-compliance to the standard is required to enable the processor to return from hibernate mode without losing the contents of SDRAM. This value prevents SDRAM decay during reset, enabling the contents of SDRAM to be preserved through the hibernate reset or deep sleep reset cycle. (This command does not apply to all processors).
Commands valid only when passed to the adi_pwr_SetVoltageRegulator function.	
ADI_PWR_CMD_SET_VR_VLEV	ADI_PWR_VLEV value specifying the voltage level required of the voltage regulator. See "ADI_PWR_VLEV" on page 3-53.
ADI_PWR_CMD_SET_VR_FREQ	ADI_PWR_VR_FREQ value specifying the required voltage regulator switching oscillator frequency. Use the ADI_PWR_FREQ_POWERDOWN value to bypass the on-board voltage regulator. See "ADI_PWR_VR_FREQ" on page 3-55.
ADI_PWR_CMD_SET_VR_GAIN	ADI_PWR_VR_GAIN value specifying the internal loop gain of the switching regulator loop (see "ADI_PWR_VR_GAIN" on page 3-55).
ADI_PWR_CMD_SET_VR_WAKE	ADI_PWR_VR_WAKE value specifying if the voltage regulator is awakened from powerdown upon an interrupt from the RTC or a low- going edge on the RESET# pin. See "ADI_PWR_VR_WAKE" on page 3-56.
ADI_PWR_CMD_SET_VR_PHYWE	ADI_PWR_VR_PHYWE enumeration value indicating whether to enable/disable the PHYWE bit (processors with PHYWE bit only). See "ADI_PWR_VR_PHYWE" on page 3-56.
ADI_PWR_CMD_SET_VR_CANWE	ADI_PWR_VR_CANWE enumeration value indicating whether to enable or disable the CANWE bit (for processors with CAN interface only). See "ADI_PWR_VR_CANWE" on page 3-54.

Table 3-6. ADI_PWR_COMMAND Available Commands (Cont'd)

Command	Associated Data Value
ADI_PWR_CMD_SET_VR_CLKBUFOE	ADI_PWR_VR_CLKBUFOE enumeration value indicating whether to enable or disable the CLKBUFOE bit (processors with CLKBUFOE bit only). See "ADI_PWR_VR_CLKBUFOE" on page 3-55.
ADI_PWR_CMD_SET_VR_CKELOW	ADI_PWR_VR_CKELOW enumeration value indicating whether to enable or disable the CKELOW bit (processors with CKELOW bit only). See "ADI_PWR_VR_CKELOW" on page 3-54.
ADI_PWR_CMD_SET_VR_USBWE	ADI_PWR_VR_USBWE enumeration value indicating whether to enable/disable the USB wakeup bit. See "ADI_PWR_VR_USBWE" on page 3-54.
Commands valid only when passed to the adi_pwr_Control function.	
ADI_PWR_CMD_GET_VDDINT	ADI_PWR_VLEV value containing the maximum core voltage level. See "ADI_PWR_VLEV" on page 3-53.
ADI_PWR_CMD_GET_VR_VLEV	ADI_PWR_VLEV value containing the current voltage level of the internal voltage regulator. Not applicable when the internal regulator is bypassed. See "ADI_PWR_VLEV" on page 3-53.
ADI_PWR_CMD_GET_VR_FREQ	ADI_PWR_FREQ value containing the current voltage regulator switching oscillator frequency. See "ADI_PWR_VR_FREQ" on page 3-55.
ADI_PWR_CMD_GET_VR_GAIN	ADI_PWR_GAIN value containing the internal loop gain of the switching regulator loop. See "ADI_PWR_VR_GAIN" on page 3-55.
ADI_PWR_CMD_GET_VR_WAKE	ADI_PWR_VR_WAKE value specifying if the voltage can be awakened from power-down upon an interrupt from the RTC or a low-going edge on the RESET# pin. See "ADI_PWR_VR_WAKE" on page 3-56.

Table 3-6. ADI_PWR_COMMAND Available Commands (Cont'd)

Command	Associated Data Value
ADI_PWR_CMD_GET_VR_PHYWE	ADI_PWR_VR_PHYWE enumeration value indicating if the PHYWE bit has been enabled/disabled (processors with PHYWE bit only). See "ADI_PWR_VR_PHYWE" on page 3-56.
ADI_PWR_CMD_GET_VR_CANWE	ADI_PWR_VR_CANWE enumeration value indicating if the CAN wakeup bit has been enabled/disabled (processors with CAN interface only). See "ADI_PWR_VR_CANWE" on page 3-54.
ADI_PWR_CMD_GET_VR_USBWE	ADI_PWR_VR_USBWE enumeration value indicating if the USB wakeup bit has been enabled/disabled (processors with USB interface only). See "ADI_PWR_VR_USBWE" on page 3-54
ADI_PWR_CMD_GET_VR_CLKBUFOE	ADI_PWR_VR_CLKBUFOE enumeration value indicating if the CLKBUFOE bit has been enabled or disabled (processors with CLKBUFOE bit only). See "ADI_PWR_VR_CLKBUFOE" on page 3-55.
ADI_PWR_CMD_GET_VR_CKELOW	ADI_PWR_VR_CKELOW enumeration value indicating if the CKELOW bit has been enabled or disabled (processors with CKELOW bit only). See "ADI_PWR_VR_CKELOW" on page 3-54.
ADI_PWR_CMD_GET_PLL_LOCKCNT	u16 value containing the value in the PLL_LOCKCNT register.

ADI_PWR_COMMAND_PAIR

This data type is used to generate a table of control commands. These commands are sent to the power management module via the `adi_pwr_Init`, `adi_pwr_SetVoltageRegulator`, and `adi_pwr_Control` functions:

```
typedef struct _ADI_PWR_COMMAND_PAIR {
        ADI_PWR_COMMAND kind;
        void *value;
} ADI_PWR_COMMAND_PAIR;
```

Refer to "ADI_PWR_COMMAND" on page 3-42 for valid values of the `kind` field.

ADI_PWR_CSEL

This data type defines the core clock divider bit field in the `PLL_DIV` register. Valid values are:

`ADI_PWR_CSEL_1`	Divides voltage core oscillator frequency by 1.
`ADI_PWR_CSEL_2`	Divides voltage core oscillator frequency by 2.
`ADI_PWR_CSEL_4`	Divides voltage core oscillator frequency by 4.
`ADI_PWR_CSEL_8`	Divides voltage core oscillator frequency by 4.

ADI_PWR_DF

This data type defines the values for the DF bit in the PLL control register. A value of ADI_PWR_DF_ON causes the value of CLKIN/2 to be passed to the PLL module. According to the *ADSP-BF533 Blackfin Processor Hardware Reference*, this leads to lower power dissipation[1].

ADI_PWR_DF_NONE	Indicates that no PLL input divider value is to be set.
ADI_PWR_DF_OFF	Pass CLKIN to the PLL.
ADI_PWR_DF_ON	Pass CLKIN/2 to the PLL.

ADI_PWR_INPUT_DELAY

This data type defines the values that the input delay bit can take in the PLL control register.

ADI_PWR_INPUT_DELAY_DISABLE	Do not add input delay.
ADI_PWR_INPUT_DELAY_ENABLE	Add approximately 200 ps of delay to the time when inputs are latched on the external memory interface.

ADI_PWR_OUTPUT_DELAY

This data type defines the values that the output delay bit can take in the PLL control register.

ADI_PWR_OUTPUT_DELAY_DISABLE	Do not add output delay.
ADI_PWR_OUTPUT_DELAY_ENABLE	Add approximately 200 ps of delay to external memory output signals.

[1] See *ADSP-BF533 Blackfin Processor Hardware Reference*, Revision 3.2, July 2006, page 8-4.

ADI_PWR_MODE

This data type defines the power mode of the processor. Valid power mode values are:

ADI_PWR_MODE_FULL_ON	Processor is in full-on mode; clock speeds are as programmed.
ADI_PWR_MODE_ACTIVE	Processor is in active mode with only L1 DMA access allowed. CCLK and SCLK are pegged to CLKIN as the PLL controller is bypassed, providing medium power saving.
ADI_PWR_MODE_ACTIVE_PLLDISABLED	Processor is in active mode with only L1 DMA access allowed. CCLK and SCLK are pegged to CLKIN as the PLL controller is bypassed *and* disabled, providing medium power saving.
ADI_PWR_MODE_SLEEP	Processor is in sleep mode. It can be woken up with any interrupt appropriately masked in the SIC_IWR register, providing high power saving.
ADI_PWR_MODE_DEEP_SLEEP	Processor is in deep sleep mode. It can only be woken up with an appropriately-masked RTC interrupt or reset, providing high power saving.
ADI_PWR_MODE_HIBERNATE	Processor is in hibernate mode. It can only be awakened on system reset, providing maximum power saving.

ADI_PWR_PACKAGE_KIND

This data type defines the package type of the processor. Along with the external voltage ("ADI_PWR_VDDEXT" on page 3-53). This value determines the heat dissipation of the part.

ADI_PWR_PACKAGE_MBGA	MBGA - identified by the hemispherical contacts on the under surface of the processor.
ADI_PWR_PACKAGE_LQFP	LQFP - identified by the leg contacts around the edges of the processor.

ADI_PWR_PCC133_COMPLIANCE

This data type defines the valid values for setting PC-133 compliance or otherwise. This value governs whether the SCKE pin on the processor is asserted on reset.

ADI_PWR_PC133_COMPLIANCE_DISABLED	SCKE is asserted on reset; SDRAM contents are invalidated.
ADI_PWR_PC133_COMPLIANCE_ENABLED	SCKE is not asserted on reset; SDRAM contents are maintained.

ADI_PWR_PROC_KIND

This data type defines the processor variant, which governs the appropriate limits for speed selection. The list of processor variants is constantly updated as new processors are introduced. For a complete list of the supported processor variants, see the Power Management Service API header file, adi_pwr.h. In addition to the ADI_PWR_PROC_KIND data type, also refer to the "equivalents" for each processor family.

ADI_PWR_RESULT

The power management module functions return a result code of the enumeration type, ADI_PWR_RESULT. Table 3-7 lists and describes the PM module return values.

Table 3-7. PM Module Return Values

Return Value	Explanation
ADI_PWR_RESULT_SUCCESS	Routine completed successfully.
ADI_PWR_RESULT_FAILED	Generic failure was encountered.
ADI_PWR_RESULT_NO_MEMORY	Insufficient memory for configuration values to be stored.
ADI_PWR_RESULT_BAD_COMMAND	Command is not recognized.

Table 3-7. PM Module Return Values (Cont'd)

Return Value	Explanation
ADI_PWR_RESULT_NOT_INITIALIZED	Function call has been ignored with no action taken, due to the PM module not being initialized.
ADI_PWR_RESULT_ALREADY_INITIALIZED	A call to adi_pwr_Init has been ignored with no action taken, due to the PM module having already been initialized.
ADI_PWR_RESULT_INVALID_VDDEXT	Invalid external voltage level has been specified.
ADI_PWR_RESULT_INVALID_PROCESSOR	Processor type specified is invalid.
ADI_PWR_RESULT_INVALID_IVG	IVG level supplied for PLL wakeup is invalid.
ADI_PWR_RESULT_INVALID_INPUT_DELAY	Input delay value is invalid.
ADI_PWR_RESULT_INVALID_OUTPUT_DELAY	Output delay value is invalid.
ADI_PWR_RESULT_INVALID_LOCKCNT	PLL lock count value is invalid.
ADI_PWR_RESULT_INVALID_MODE	Invalid operating mode has been specified.
ADI_PWR_RESULT_INVALID_CSEL	Invalid value for CSEL has been specified.
ADI_PWR_RESULT_INVALID_SSEL	Invalid value for SSEL has been specified.
ADI_PWR_INVALID_CSEL_SSEL_COMBINATION	Core clock divider is greater that the system clock divider value, or both ADI_PWR_CSEL_NONE and ADI_PWR_SSEL_NONE are specified.
ADI_PWR_RESULT_VOLTAGE_REGULATOR_BYPASSED	Voltage regulator cannot be set since it is in bypass mode.
ADI_PWR_RESULT_INVALID_VR_VLEV	VLEV argument is invalid or insufficient to sustain the current core and system clock frequencies.

Table 3-7. PM Module Return Values (Cont'd)

Return Value	Explanation
ADI_PWR_RESULT_INVALID_VR_FREQ	FREQ value is invalid.
ADI_PWR_RESULT_INVALID_VR_GAIN	GAIN value is invalid.
ADI_PWR_RESULT_INVALID_VR_WAKE	WAKE value is invalid.
ADI_PWR_RESULT_INVALID_VR_PHYWE	PHYWE value is invalid.
ADI_PWR_RESULT_INVALID_VR_CANWE	CAN wakeup value is invalid.
ADI_PWR_RESULT_INVALID_VR_USBWE	USB wakeup value is invalid.
ADI_PWR_RESULT_INVALID_VR_CLKBUFOE	CLKBUFOE value is invalid.
ADI_PWR_RESULT_INVALID_VR_CKELOW	CKELOW value is invalid.
ADI_PWR_RESULT_INVALID_VR_USBWE	USBWE wakeup value is invalid.

ADI_PWR_SSEL

This data type defines the system clock divider bit field in the PLL_DIV register. Valid values are:

ADI_PWR_SSEL_1	Divides voltage core oscillator frequency by 1.
ADI_PWR_SSEL_2	Divides voltage core oscillator frequency by 2.
ADI_PWR_SSEL_3	Divides voltage core oscillator frequency by 3.
ADI_PWR_SSEL_4	Divides voltage core oscillator frequency by 4.
ADI_PWR_SSEL_5	Divides voltage core oscillator frequency by 5.
ADI_PWR_SSEL_6	Divides voltage core oscillator frequency by 6.
ADI_PWR_SSEL_7	Divides voltage core oscillator frequency by 7.
ADI_PWR_SSEL_8	Divides voltage core oscillator frequency by 8.
ADI_PWR_SSEL_9	Divides voltage core oscillator frequency by 9.
ADI_PWR_SSEL_10	Divides voltage core oscillator frequency by 10.
ADI_PWR_SSEL_11	Divides voltage core oscillator frequency by 11.
ADI_PWR_SSEL_12	Divides voltage core oscillator frequency by 12.

ADI_PWR_SSEL_13	Divides voltage core oscillator frequency by 13.
ADI_PWR_SSEL_14	Divides voltage core oscillator frequency by 14.
ADI_PWR_SSEL_15	Divides voltage core oscillator frequency by 15.

ADI_PWR_VDDEXT

This data type defines the external voltage (VDDEXT) supplied to the voltage regulator.

ADI_PWR_VDDEXT_330	3.3 V
ADI_PWR_VDDEXT_250	2.5 V

ADI_PWR_VLEV

This data type defines the acceptable voltage levels for the voltage regulator. The values for ADSP-BF533 and ADSP-BF561 processors are:

ADI_PWR_VLEV_085	0.85 V
ADI_PWR_VLEV_090	0.90 V
ADI_PWR_VLEV_095	0.95 V
ADI_PWR_VLEV_100	1.00 V
ADI_PWR_VLEV_105	1.05 V
ADI_PWR_VLEV_110	1.10 V
ADI_PWR_VLEV_115	1.15 V
ADI_PWR_VLEV_120	1.20 V (default)
ADI_PWR_VLEV_125	1.25 V
ADI_PWR_VLEV_130	1.30 V
ADI_PWR_VLEV_135	1.35 V
ADI_PWR_VLEV_140	1.40 V

ADI_PWR_VR_CANWE

This data type defines the valid values for the CANWE bit in the voltage regulator control register. If enabled, the voltage regulator can be awakened from power-down by activity on the controller area network (CAN) interface.

ADI_PWR_VR_CANWE_DISABLED	Disable wakeup by CAN activity.
ADI_PWR_VR_CANWE_ENABLED	Enable wakeup by CAN activity.

ADI_PWR_VR_USBWE

This data type defines the valid values for the USBWE bit in the voltage regulator control register. If enabled, the voltage regulator can be awakened from power-down by activity on the universal serial bus (USB) interface.

ADI_PWR_VR_USBWE_DISABLED	Disable wakeup by USB activity.
ADI_PWR_VR_USBWE_ENABLED	Enable wakeup by USB activity.

ADI_PWR_VR_CKELOW

This data type defines the valid values for the CKELOW bit in the voltage regulator control register. If enabled, the SCKE pin is driven low on system reset to enable the SDRAM to remain in self-refresh mode.

ADI_PWR_VR_PHYWE_DISABLED	Drive SCKE high on reset; SDRAM contents are invalidated.
ADI_PWR_VR_PHYWE_ENABLED	Drive SCKE low on reset; SDRAM contents are maintained.

ADI_PWR_VR_CLKBUFOE

This data type defines the valid values for the CLKBUFOE bit in the voltage regulator control register. If enabled, the CLKIN signal can be shared with peripheral devices, especially the Ethernet PHY.

ADI_PWR_VR_CLKBUFOE_DISABLED	Disable CLKIN sharing.
ADI_PWR_VR_CLKBUFOE_ENABLED	Enable CLKIN sharing.

ADI_PWR_VR_FREQ

This data type defines the acceptable switching frequency values for the voltage regulator. Its value is linked to the switching capacitor and inductor values. The higher the frequency setting, the smaller the capacitor and inductor values. The valid values for all Blackfin processors are:

ADI_PWR_VR_FREQ_POWERDOWN	Power-down/bypass onboard regulation
ADI_PWR_VR_FREQ_333KHZ	333 kHz
ADI_PWR_VR_FREQ_667KHZ	667 kHz
ADI_PWR_VR_FREQ_1MHZ	1 MHz (default)

ADI_PWR_VR_GAIN

This data type defines the acceptable values for the internal loop gain of the switching regulator loop. The gain controls how quickly the voltage output settles on its final value. The higher the gain, the quicker the settling time. High gain settings cause greater overshoot in the process.

ADI_PWR_VR_GAIN_5	5
ADI_PWR_VR_GAIN_110	10
ADI_PWR_VR_GAIN_20	20 (default)
ADI_PWR_VR_GAIN_50	50

ADI_PWR_VR_PHYWE

This data type defines the values for the PHYWE bit in the voltage regulator control register. If enabled, the voltage regulator can be awakened from power-down by activity on the PHY interface.

ADI_PWR_VR_PHYWE_DISABLED	Disable wakeup by PHY activity.
ADI_PWR_VR_PHYWE_ENABLED	Enable wakeup by PHY activity.

ADI_PWR_VR_WAKE

This data type defines the values for the WAKE bit in the voltage regulator control register. If enabled (ADI_PWR_VR_WAKE_ENABLED), the voltage regulator can be awakened from power-down (ADI_PWR_VR_FREQ_POWERDOWN) upon an RTC interrupt or a low-going edge on the RESET pin.

ADI_PWR_VR_WAKE_DISABLED	Disables wakeup by RTC and RESET.
ADI_PWR_VR_WAKE_ENABLED	Enables wakeup by RTC and RESET.

PM Module Macros

Table 3-8 lists and describes PM module macros.

Table 3-8. PM Module Macros

Macro	Explanation
ADI_PWR_VLEV_DEFAULT	Default/reset voltage level ADI_PWR_VLEV_130
ADI_PWR_VLEV_MIN	Minimum voltage level ADI_PWR_VLEV_085
ADI_PWR_VLEV_MAX	Maximum voltage level ADI_PWR_VLEV_120
ADI_PWR_VOLTS(V)	Returns the voltage in volts as a float for the given level.
ADI_PWR_MILLIVOLTS(V)	Returns an integer value of the voltage in millivolts for the given level.

Table 3-8. PM Module Macros (Cont'd)

Macro	Explanation
ADI_PWR_VR_FREQ_DEFAULT	Default/reset switching frequency value, ADI_PWR_FREQ_1MHZ
ADI_PWR_VR_FREQ_MIN	Minimum switching frequency value, ADI_PWR_FREQ_POWERDOWN
ADI_PWR_VR_FREQ_MAX	Maximum switching frequency value, ADI_PWR_FREQ_1MHZ
ADI_PWR_VR_GAIN_DEFAULT	Default/reset voltage regulator gain value, ADI_PWR_GAIN_20
ADI_PWR_VR_GAIN_MIN	Minimum voltage regulator gain value, ADI_PWR_GAIN_5
ADI_PWR_VR_GAIN_MAX	Default/reset voltage regulator gain value, ADI_PWR_GAIN_20
ADI_PWR_PROC_BF533SKBCZ600	Equivalent processor type to ADI_PWR_PROC_BF533SKBC600
ADI_PWR_PROC_BF533SBBZ500	Equivalent processor type to ADI_PWR_PROC_BF533SBBC500
ADI_PWR_PROC_BF532SBBC400	Equivalent processor type to ADI_PWR_PROC_BF531_OR_BF532
ADI_PWR_PROC_BF532SBST400	Equivalent processor type to ADI_PWR_PROC_BF531_OR_BF532
ADI_PWR_PROC_BF532SBBZ400	Equivalent processor type to ADI_PWR_PROC_BF531_OR_BF532
ADI_PWR_PROC_BF531SBBC400	Equivalent processor type to ADI_PWR_PROC_BF531_OR_BF532
ADI_PWR_PROC_BF531SBST400	Equivalent processor type to ADI_PWR_PROC_BF531_OR_BF532
ADI_PWR_PROC_BF531SBSTZ400	Equivalent processor type to ADI_PWR_PROC_BF531_OR_BF532.
ADI_PWR_PROC_BF531SBBZ400	Equivalent processor type to ADI_PWR_PROC_BF531_OR_BF532

Table 3-8. PM Module Macros (Cont'd)

Macro	Explanation
ADI_PWR_PACKAGE_PBGA	Equivalent package type to ADI_PWR_PACKAGE_MBGA
ADI_PWR_PROC_BF537SKBC600	Equivalent processor type to ADI_PWR_PROC_BF537SKBC1600
ADI_PWR_PROC_BF537SKBC1Z600	Equivalent processor type to ADI_PWR_PROC_BF537SKBC1600
ADI_PWR_PROC_BF537SKBC2Z600	Equivalent processor type to ADI_PWR_PROC_BF537SKBC1600
ADI_PWR_PROC_BF537SBBC1Z500	Equivalent processor type to ADI_PWR_PROC_BF537SBBC1500
ADI_PWR_PROC_BF537SBBC2Z500	Equivalent processor type to ADI_PWR_PROC_BF537SBBC1500
ADI_PWR_PROC_BF536SBBC1Z400	Equivalent processor type to ADI_PWR_PROC_BF536SBBC1400
ADI_PWR_PROC_BF536SBBC2Z400	Equivalent processor type to ADI_PWR_PROC_BF536SBBC1400
ADI_PWR_PROC_BF536SBBC1Z300	Equivalent processor type to ADI_PWR_PROC_BF536SBBC1300
ADI_PWR_PROC_BF536SBBC2Z300	Equivalent processor type to ADI_PWR_PROC_BF536SBBC1300
ADI_PWR_PROC_BF534SBBC1Z400	Equivalent processor type to ADI_PWR_PROC_BF534SBBC1400
ADI_PWR_PROC_BF534SBBC2Z400	Equivalent processor type to ADI_PWR_PROC_BF534SBBC1400
ADI_PWR_PROC_BF534SBBC1Z500	Equivalent processor type to ADI_PWR_PROC_BF534SBBC1500
ADI_PWR_PROC_BF534SBBC2Z500	Equivalent processor type to ADI_PWR_PROC_BF534SBBC1500
ADI_PWR_PROC_BF541SKBC1600	Equivalent processor type to ADI_PWR_PROC_BF548SKBC1600

Table 3-8. PM Module Macros (Cont'd)

Macro	Explanation
ADI_PWR_PROC_BF541SBBC1533	Equivalent processor type to ADI_PWR_PROC_BF548SBBC1533
ADI_PWR_PROC_BF541SBBC1400	Equivalent processor type to ADI_PWR_PROC_BF548SBBC1400
ADI_PWR_PROC_BF542SKBC1600	Equivalent processor type to ADI_PWR_PROC_BF548SKBC1600
ADI_PWR_PROC_BF542SBBC1533	Equivalent processor type to ADI_PWR_PROC_BF548SBBC1533
ADI_PWR_PROC_BF542SBBC1400	Equivalent processor type to ADI_PWR_PROC_BF548SBBC1400
ADI_PWR_PROC_BF544SKBC1600	Equivalent processor type to ADI_PWR_PROC_BF548SKBC1600
ADI_PWR_PROC_BF544SBBC1533	Equivalent processor type to ADI_PWR_PROC_BF548SBBC1533
ADI_PWR_PROC_BF544SBBC1400	Equivalent processor type to ADI_PWR_PROC_BF548SBBC1400
ADI_PWR_PROC_BF549SKBC1600	Equivalent processor type to ADI_PWR_PROC_BF548SKBC1600
ADI_PWR_PROC_BF549SBBC1533	Equivalent processor type to ADI_PWR_PROC_BF548SBBC1533
ADI_PWR_PROC_BF549SBBC1400	Equivalent processor type to ADI_PWR_PROC_BF548SBBC1400

4 EXTERNAL BUS INTERFACE UNIT MODULE

This chapter describes the external bus interface unit (EBIU) module. The EBIU enables the configuration of the asynchronous memory controller and the SDRAM or DDR interface. It also allows the DDR or SDRAM to be automatically adjusted in response to changes in the system clock frequency.

This chapter contains:

Introduction

The initial goal of the external bus interface unit (EBIU) module is to enable the power management module to adjust the SDRAM or DDR controller (SDC) in accordance with changes made to the system clock (SCLK) frequency. Calls to both adi_pwr_SetFreq and adi_pwr_SetMaxFreqForVolt adjust the SDC settings to the SCLK frequency selected, provided the EBIU module has been initialized. For more information, see “Power Management Module” on page 3-1.

Using the module is straightforward. The adi_ebiu_Init function is called to set up the relevant values listed in the appropriate data sheet for the external memory device. Thereafter, the refresh rate for SDRAM or DDR is adjusted automatically each time the power management module changes SCLK. The asynchronous memory controller is not automatically adjusted but can be explicitly reconfigured via a call to adi_ebiu_Control. The “Using the EBIU Module” section provides a step-by-step description of how to work with the EBIU module. Sample code is also included.

The EBIU module uses an unambiguous naming convention to safeguard against conflicts with other software libraries provided by Analog Devices or other companies. All enumeration values and typedef statements use the ADI_EBIU_ prefix, and functions and global variables use the lowercase equivalent, adi_ebiu_.

Two versions of the library are available for each processor, corresponding to the debug and release configurations in VisualDSP++. In addition to the usual defaults for the debug configuration, the API functions perform checks on the passed arguments and report appropriate error codes, as required. In the release version of the library, most functions return one of two result codes: ADI_EBIU_RESULT_SUCCESS on successful completion, or ADI_EBIU_RESULT_NOT_INITIALIZED when the EBIU module has not been initialized prior to the function call.

Using the EBIU Module

The first step to using the EBIU module involves setting up the necessary parameters for the external memory interfaces that are used. In this step, a table of command-value pairs is passed to the `adi_ebiu_Init` function. The information required is described in detail in `adi_ebiu_Init` in the Description section (on page 4-16). The amount and the type of information that must be passed depends on the individual board configuration.

In the following example, assume that the ADSP-BF533 EZ-KIT Lite (Rev 2.1) is configured. Specify the command-pair table as follows:

```
/* Asynch global control register field - clkout enable */
ADI_EBIU_ASYNCH_CLKOUT clkout_enable =
ADI_EBIU_ASYNCH_CLKOUT_ENABLE;
/* Asynch global control register field - select which banks to
enable */
ADI_EBIU_ASYNCH_BANK_ENABLE banks_enable =
ADI_EBIU_ASYNCH_BANK0_1_2_3;
/* Asynch bank timing parameters, using same value for all 4
banks - specified in either cycles or timing units, but NOT BOTH,
*/
ADI_EBIU_ASYNCH_BANK_TIMING asynch_bank_trans_time =
{ADI_EBIU_BANK_ALL, { ADI_EBIU_ASYNCH_TT_4_CYCLES, { 0,
ADI_EBIU_TIMING_UNIT_NANOSEC } }
ADI_EBIU_ASYNCH_BANK_TIMING asynch_bank_setup_time =
{ADI_EBIU_BANK_ALL, { ADI_EBIU_ASYNCH_ST_3_CYCLES, { 0,
ADI_EBIU_TIMING_UNIT_NANOSEC } } };
ADI_EBIU_ASYNCH_BANK_TIMING asynch_bank_hold_time =
{ADI_EBIU_BANK_ALL, { ADI_EBIU_ASYNCH_HT_2_CYCLES, { 0,
ADI_EBIU_TIMING_UNIT_NANOSEC } } };
ADI_EBIU_ASYNCH_BANK_TIMING asynch_bank_read_access_time =
{ADI_EBIU_BANK_ALL, { 0xB, { 0, ADI_EBIU_TIMING_UNIT_NANOSEC } }
};
```

```
ADI_EBIU_ASYNCH_BANK_TIMING asynch_bank_write_access_time =
{ADI_EBIU_BANK_ALL, { 7, { 0, ADI_EBIU_TIMING_UNIT_NANOSEC } } };
ADI_EBIU_ASYNCH_BANK_VALUE asynch_bank_ardy_enable = {
ADI_EBIU_BANK_ALL, { ardy_enable: ADI_EBIU_ASYNCH_ARDY_DISABLE }
};
ADI_EBIU_ASYNCH_BANK_VALUE asynch_bank_ardy_polarity = {
ADI_EBIU_BANK_ALL, { ardy_polarity:
ADI_EBIU_ASYNCH_ARDY_POLARITY_LOW } };
/* SDRAM timing parameters, specified according to data sheet */
ADI_EBIU_TIMING_VALUE   twrmin  = {1,{7500,
ADI_EBIU_TIMING_UNIT_PICOSEC}};  /* set min TWR to 1 SCLK cycle +
7.5ns */
ADI_EBIU_TIMING_VALUE   refresh = {8192,{64,
ADI_EBIU_TIMING_UNIT_MILLISEC}}; /* set refresh period to 8192
cycles in 64ms */
ADI_EBIU_TIME     trasmin  = {44, ADI_EBIU_TIMING_UNIT_NANOSEC};
/* set min TRAS to 44ns */
ADI_EBIU_TIME      trpmin   = {20, ADI_EBIU_TIMING_UNIT_NANOSEC};
    /* set min TRP to 20ns */
ADI_EBIU_TIME     trcdmin  = {20, ADI_EBIU_TIMING_UNIT_NANOSEC};
/* set min TRCD to 20ns */
u32      cl_threshold = 100; /* set cl threshold to 100 Mhz */
ADI_EBIU_SDRAM_BANK_VALUE bank_size = { 0, { size:
ADI_EBIU_SDRAM_BANK_64MB }};     /* bank size is 64MB */
ADI_EBIU_SDRAM_BANK_VALUE bank_width = { 0, {
width: ADI_EBIU_SDRAM_BANK_COL_10BIT }};  /* column address width
is 10-Bit */
/* set up the command pair table using the above definitions */
ADI_EBIU_COMMAND_PAIR ebiu_init_table[] = {
 { ADI_EBIU_CMD_SET_SDRAM_BANK_SIZE, (void*)&bank_size },
 { ADI_EBIU_CMD_SET_SDRAM_BANK_COL_WIDTH, (void*)&bank_width },
 { ADI_EBIU_CMD_SET_SDRAM_CL_THRESHOLD, (void*)cl_threshold },
 { ADI_EBIU_CMD_SET_SDRAM_TRASMIN, (void*)&trasmin },
 { ADI_EBIU_CMD_SET_SDRAM_TRPMIN, (void*)&trpmin },
```

```
 { ADI_EBIU_CMD_SET_SDRAM_TRCDMIN, (void*)&trcdmin },
 { ADI_EBIU_CMD_SET_SDRAM_TWRMIN, (void*)&twrmin },
 { ADI_EBIU_CMD_SET_SDRAM_REFRESH, (void*)&refresh },
 { ADI_EBIU_CMD_SET_ASYNCH_CLKOUT_ENABLE, (void*)&clkout_enable
},
 { ADI_EBIU_CMD_SET_ASYNCH_BANK_ENABLE, (void*)&banks_enable },
 { ADI_EBIU_CMD_SET_ASYNCH_BANK_TRANSITION_TIME,
(void*)&asynch_bank_trans_time },
 { ADI_EBIU_CMD_SET_ASYNCH_BANK_READ_ACCESS_TIME,
(void*)&asynch_bank_read_access_time },
 { ADI_EBIU_CMD_SET_ASYNCH_BANK_WRITE_ACCESS_TIME,
(void*)&asynch_bank_write_access_time },
 { ADI_EBIU_CMD_SET_ASYNCH_BANK_SETUP_TIME,
(void*)&asynch_bank_setup_time },
 { ADI_EBIU_CMD_SET_ASYNCH_BANK_HOLD_TIME,
(void*)&asynch_bank_hold_time },
 { ADI_EBIU_CMD_SET_ASYNCH_BANK_ARDY_ENABLE,
(void*)&asynch_bank_ardy_enable },
 { ADI_EBIU_CMD_SET_ASYNCH_BANK_ARDY_POLARITY,
(void*)&asynch_bank_ardy_polarity },
 { ADI_EBIU_CMD_END, 0 }
};
```

The second argument in the call to `adi_ebiu_Init` is reserved and should be set to zero. The EBIU module should be initialized prior to initializing the power management module, so that subsequent calls to `adi_pwr_SetFreq` or `adi_pwr_SetMaxFreqForVolt` in the power management module will automatically adjust the SDRAM or DDR.

To illustrate what is required for Blackfin processors that support DDR memory, a command table is shown below. Replace the SDRAM parameters, above, with the DDR parameters shown below, and add the asynchronous memory controller commands shown in the above example.

```
ADI_EBIU_TIMING_VALUE RC     { 8, {60,
ADI_EBIU_TIMING_UNIT_NANOSEC  }};      /* cycles between one
  active command and the next */
ADI_EBIU_TIMING_VALUE RAS =  { 6, {42,
ADI_EBIU_TIMING_UNIT_NANOSEC  }};      /* cycles between active
  command and precharge command */
ADI_EBIU_TIMING_VALUE RP =   { 2, {15,
ADI_EBIU_TIMING_UNIT_NANOSEC  }};      /* cycles between
  precharge command and active command */
ADI_EBIU_TIMING_VALUE RFC =   { 10,{72,
ADI_EBIU_TIMING_UNIT_NANOSEC  }};      /* cycles for SDRAM to
  recover from REFRESH signal */
ADI_EBIU_TIMING_VALUE WTR =   { 2,
{7500,ADI_EBIU_TIMING_UNIT_PICOSEC }}; /* cycles from last write
  data until next read command */
ADI_EBIU_TIMING_VALUE tWR =   { 2, {15,
ADI_EBIU_TIMING_UNIT_NANOSEC  }};      /* write recovery time is
  2 or 3 cycles */
ADI_EBIU_TIMING_VALUE tMRD =  { 2, {15,
ADI_EBIU_TIMING_UNIT_NANOSEC  }};       /* cycles from setting of
  mode */
ADI_EBIU_TIMING_VALUE RCD =   { 2, {15,
ADI_EBIU_TIMING_UNIT_NANOSEC  }};      /* cycles from active
  command to next R/W */
ADI_EBIU_TIMING_VALUE REFI =  { 1037,{7777,
ADI_EBIU_TIMING_UNIT_NANOSEC}};       /* cycles from one REFRESH
  signal to the next */
```

```
ADI_EBIU_COMMAND_PAIR ebiu_init_table[] = {
{ ADI_EBIU_CMD_SET_DDR_REFI,          (void*)&REFI  }, /* command
  to set refresh interval */
{ ADI_EBIU_CMD_SET_DDR_RFC,           (void*)&RFC   }, /* command
  to set auto refresh period */
{ ADI_EBIU_CMD_SET_DDR_RP,            (void*)&RP    }, /* command
  to set precharge to active time */
{ ADI_EBIU_CMD_SET_DDR_RAS,           (void*)&RAS   }  /* command
  to set active to precharge time */
{ ADI_EBIU_CMD_SET_DDR_RC,            (void*)&RC    }, /* command
  to set active to active time */
{ ADI_EBIU_CMD_SET_DDR_WTR,           (void*)&WTR   }, /* command
  to set write to read time */
{ ADI_EBIU_CMD_SET_DDR_DEVICE_SIZE,  (void*)0      },  /* command
  to set size of device */
{ ADI_EBIU_CMD_SET_DDR_CAS,           (void*)2      }, /* command
  to set cycles from assertion of R/W until first valid data */
{ ADI_EBIU_CMD_SET_DDR_DEVICE_WIDTH, (void*)2     }, /* command
  to set width of device */
{ ADI_EBIU_CMD_SET_DDR_EXTERNAL_BANKS,(void*)0    }, /* command
  to set number of external banks */
{ ADI_EBIU_CMD_SET_DDR_DATA_WIDTH,    (void*)2    }, /* command
  to set data width */
{ ADI_EBIU_CMD_SET_DDR_WR,            (void*)&tWR }, /* command
   to set write recovery time */
{ ADI_EBIU_CMD_SET_DDR_MRD,           (void*)&tMRD },/* command
  to set cycles from setting mode reg until next command */
{ ADI_EBIU_CMD_SET_DDR_RCD,           (void*)&RCD  }, /* command
  to set cycles from active command to a read-write assertion */

{ ADI_EBIU_CMD_END, 0                               }  /* indicate
the last command of the table */
};
```

In the sample code above, note that the SDRAM minimum TWR value is defined as a structure called ADI_EBIU_TIMING_VALUE which consists of two main parts: a number of cycles, and a number of timing units, in this case, picoseconds. This representation reflects the definition found in the appropriate SDRAM data sheet where the value is expressed as one cycle of SCLK plus 7.5 ns. For the SDRAM refresh period, this structure expresses the time taken for the given number of refresh cycles. The sample code shows that the refresh period is 64 milliseconds, which takes 8192 cycles.

For hardware that uses a Micron SDRAM module, the command-pair table can be abbreviated to just specify the type of the module and the size of the bank, as shown below, adding asynchronous memory controller commands, as needed:

```
ADI_EBIU_SDRAM_BANK_VALUE bank_size;
// set bank size to 32MB
bank_size.value.size = ADI_EBIU_SDRAM_BANK_32MB;
ADI_EBIU_COMMAND_PAIR ebiu_init_table[] = {
    // MT48LC16M16-75 module
    { ADI_EBIU_CMD_SET_SDRAM_MODULE,
    (void*)ADI_EBIU_SDRAM_MODULE_MT48LC16M16A2_75 },
    { ADI_EBIU_CMD_SET_SDRAM_BANK_SIZE, (void*)&bank_size },
    { ADI_EBIU_CMD_END, 0 }
};
adi_ebiu_Init(ebiu_init_table, 0);
```

Further changes can be made at any time by passing command-value pairs or tables of pairs to adi_ebiu_Control. For example, to pass a single command-value pair to enable the SDRAM to self-refresh during inactivity, the following code could be used:

```
adi_ebiu_Control(
        ADI_EBIU_CMD_SET_SDRAM_SRFS,
        (void*)ADI_EBIU_SDRAM_SRFS_ENABLE
);
```

Since the SDRAM settings are closely tied to the system clock (SCLK) frequency, the direct use of the adi_ebiu_AdjustSDRAM function from within a client application is not required since it is called automatically by the appropriate functions in the power management module when SCLK changes.

EBIU API Reference

This section provides descriptions of the EBIU module's API functions.

Notation Conventions

The reference pages for the API functions use the following format:

Name – Name and purpose of the function

Description – Function specification

Prototype – Required header file and functional prototype

Arguments – Description of function arguments

Return Value – Description of function return values

adi_ebiu_AdjustSDRAM

Description

For the passed system clock (SCLK) frequency, the adi_ebiu_AdjustSDRAM function calculates and sets the following values for SDRAM: the TRAS, TRP, TRCD, and TWR values in the EBIU_SDGCTL register and the RDIV value in the EBIU_SDRRC register. The function calculates and sets the following values for DDR: the RAS, RP, RFC, REFI, and RC values in the DDRCTL0 register and the RCD, MRD, and WR values in the DDRCTL1 register.

This function is primarily used by the power management module to ensure that SDRAM settings are optimal for the processor's current SCLK frequency.

The adi_ebiu_AdjustSDRAM function returns without making any changes if the SDRAM has not been successfully initialized with a call to adi_ebiu_Init.

Prototype

```
void adi_ebiu_AdjustSDRAM(
            const u32 fsclk
);
```

Arguments

fsclk	System clock (SCLK) frequency in MHz

Return Value

The function returns the following values in debug or release mode.

ADI_EBIU_RESULT_SUCCESS	Process completed successfully.
ADI_EBIU_RESULT_NOT_INITIALIZED	SDRAM has not been successfully initialized, or SDRAM had not been enabled.

adi_ebiu_Control

Description

The `adi_ebiu_Control()` function enables the EBIU SDRAM and EBIU DDR registers to be configured according to command-value pairs using one of the following options. (See "ADI_EBIU_COMMAND_PAIR" on page 4-38.)

- A single command-value pair is passed.

```
adi_ebiu_Control(
        ADI_EBIU_CMD_SET_SDRAM_SRFS,
        (void*)ADI_EBIU_SDRAM_SRFS_ENABLE
);
```

- A single command-value pair structure is passed.

```
ADI_EBIU_COMMAND_PAIR cmd = {
        ADI_EBIU_CMD_SET_SDRAM_SRFS,
        (void*)ADI_EBIU_SDRAM_SRFS_ENABLE
};
adi_ebiu_Control(ADI_EBIU_CMD_PAIR, (void*)&cmd);
```

- A table of `ADI_EBIU_COMMAND_PAIR` structures is passed. The last command-value entry in the table must be `{ADI_EBIU_CMD_END, 0}`.

```
ADI_EBIU_COMMAND_PAIR table[] = {
    { ADI_EBIU_CMD_SET_SDRAM_FBBRW,
(void*)ADI_EBIU_SDRAM_FBBRW_ENABLE },
    { ADI_EBIU_CMD_SET_SDRAM_CDDBG,
(void*)ADI_EBIU_CDDBG_ENABLE },
    { ADI_EBIU_CMD_END, 0 }
};
```

```
adi_ebiu_Control(

        ADI_EBIU_CMD_TABLE,
        (void*)table
);
```

Refer to "ADI_EBIU_COMMAND" on page 4-31 and "Command Value Enumerations" on page 4-38 for the complete list of commands and associated values for both the SDRAM and DDR interfaces and the asynchronous memory interface.

Prototype

```
adi_EBIU_RESULT adi_ebiu_Control(
        ADI_EBIU_COMMAND command,
        void *value
);
```

Arguments

Command	ADI_EBIU_COMMAND enumeration value specifying the meaning of the associated value argument
Value	Required value. (See Description above).

Return Value

In debug mode, one of the following values listed in Table 4-1 is returned; otherwise, ADI_EBIU_RESULT_SUCCESS or ADI_EBIU_RESULT_NOT_INITIALIZED is returned, depending on whether the EBIU module has been successfully initialized.

Table 4-1. Adi_ebiu_Control Return Values

Return Value	Explanation
ADI_EBIU_RESULT_BAD_COMMAND	Command is not recognized.
ADI_EBIU_RESULT_SUCCESS	Function completed successfully.
ADI_EBIU_RESULT_NOT_INITIALIZED	EBIU module is not initialized.
ADI_EBIU_RESULT_INVALID_SDRAM_SRFS	Invalid self-refresh value is specified. See "ADI_EBIU_SDRAM_TCSR" on page 4-41.
ADI_EBIU_RESULT_INVALID_SDRAM_PUPSD	Invalid power-up start delay bit value is specified. See "ADI_EBIU_SDRAM_EBUFE" on page 4-42.
ADI_EBIU_RESULT_INVALID_SDRAM_PSM	Invalid SDRAM power-up sequence bit value is specified. See "ADI_EBIU_SDRAM_PUPSD" on page 4-42.
ADI_EBIU_RESULT_INVALID_SDRAM_EBUFE	Invalid external buffering bit value is specified. See "ADI_EBIU_SDRAM_SRFS" on page 4-41.
ADI_EBIU_RESULT_INVALID_SDRAM_FBBRW	Invalid fast back-to-back, read-to-write bit value is specified. See "ADI_EBIU_SDRAM_FBBRW" on page 4-43.
ADI_EBIU_RESULT_INVALID_SDRAM_CDDBG	Invalid control disable during bus grant bit value is specified. See "ADI_EBIU_SDRAM_CDDBG" on page 4-44.
ADI_EBIU_RESULT_INVALID_SDRAM_EBE	Invalid SDRAM enable selection. See "ADI_EBIU_SDRAM_ENABLE" on page 4-38
ADI_EBIU_RESULT_INVALID_ASYNCH_BANK_READ_ACCESS_TIME	Invalid asynchronous memory read access time
ADI_EBIU_RESULT_INVALID_ASYNCH_BANK_WRITE_ACCESS_TIME	Invalid asynchronous memory write access time
ADI_EBIU_RESULT_INVALID_ASYNCH_BANK_SETUP_TIME	Invalid asynchronous memory bank setup time
ADI_EBIU_RESULT_INVALID_ASYNCH_BANK_HOLD_TIME	Invalid asynchronous memory bank hold time

adi_ebiu_GetConfigSize

Description

The `adi_ebiu_GetConfigSize()` function returns the number of bytes required to save the current configuration data. This value is also available via the `ADI_EBIU_SIZEOF_CONFIG` macro.

Prototype

```
size_t adi_ebiu_GetConfigSize(void);
```

Return Value

The size of the configuration structure.

adi_ebiu_Init

Description

The adi_ebiu_Init function initializes the EBIU module. Currently, the module is configured to handle either a DDR or a SDRAM controller, plus an asynchronous memory controller. For the EBIU service which supports SRDRAM, the adi_ebiu_Init function sets up the EBIU_SDGCTL, EBIU_SDBCTL, and EBIU_SDRRC registers to reflect the correct SDRAM configuration attached to the processor. For the EBIU service that supports DDR, the adi_ebiu_Init function sets up the DDR control registers, DDRCTL0, DDRCTL1, and DDRCTL2. For successful initialization of the SDRAM or the DDR controller, certain values must be passed to adi_ebiu_Init, as outlined in the following two tables, one for SDRAM and one for DDR. The following table shows the values that must be passed to adi_ebiu_Init to initialize SDRAM.

Description	Command	Value Type
Bank size	ADI_EBIU_CMD_SET_SDRAM_BANK_SIZE	ADI_EBIU_SDRAM_BANK_VALUE
Bank column address width	ADI_EBIU_CMD_SET_SDRAM_BANK_COLUMN_WIDTH	ADI_EBIU_SDRAM_BANK_VALUE
CAS[1] latency threshold (MHz)	ADI_EBIU_CMD_SET_SDRAM_CL_THRESHOLD	u32
Minimum TRAS[2] (ns)	ADI_EBIU_CMD_SET_SDRAM_TRASMIN	ADI_EBIU_TIME
Min. TRP[3] (ns)	ADI_EBIU_EBIU_CMD_SET_SDRAM_TRPMIN	ADI_EBIU_TIME
Min. TRCD[4] (ns)	ADI_EBIU_CMD_SET_SDRAM_TRCDMIN	ADI_EBIU_TIME
Min. TWR[5] (cycles, ns)	ADI_EBIU_CMD_SET_SDRAM_TWRMIN	ADI_EBIU_TIMING_VALUE
Refresh period (cycles, ms)	ADI_EBIU_CMD_SET_SDRAM_REFRESH	ADI_EBIU_TIMING_VALUE

1 Column address strobe
2 Required delay between issuing a Bank Activate command and a Precharge command, and between the Self-Refresh command and the exit from self-refresh.

3 Required delay between issuing a `Precharge` command and the `Bank Activate`, `Auto-Refresh`, or `Self-Refresh` commands.
4 Required delay between issuing a `Bank Activate` command and the start of the first read/write command.
5 Required delay between a `Write` command and a `Precharge` command.

The following table shows the values that must be passed to `adi_ebiu_Init` to initialize DDR.

Description	Command	Value Type
Width of data	ADI_EBIU_CMD_SET_DDR_DATA_WIDTH	u32
Number of external banks	ADI_EBIU_CMD_SET_DDR_EXTERNAL_BANKS	u32
Width of device	ADI_EBIU_CMD_SET_DDR_DEVICE_WIDTH	u32
Size of device	ADI_EBIU_CMD_SET_DDR_DEVICE_SIZE	u32
Auto-refresh interval	ADI_EBIU_CMD_SET_DDR_REFI	ADI_EBIU_TIMING_VALUE
Auto-refresh command period	ADI_EBIU_CMD_SET_DDR_RFC	ADI_EBIU_TIMING_VALUE
Interval between R/W command and valid data	ADI_EBIU_CMD_SET_DDR_CAS	u32
Interval between active and R/W command	ADI_EBIU_CMD_SET_DDR_RCD	ADI_EBIU_TIMING_VALUE
Active to active interval	ADI_EBIU_CMD_SET_DDR_RC	ADI_EBIU_TIMING_VALUE
Active to precharge time	ADI_EBIU_CMD_SET_DDR_RAS	ADI_EBIU_TIMING_VALUE
Precharge to active time	ADI_EBIU_CMD_SET_DDR_RP	ADI_EBIU_TIMING_VALUE
Interval between setting of mode register and next command	ADI_EBIU_CMD_SET_DDR_MRD	ADI_EBIU_TIMING_VALUE
Write to read interval	ADI_EBIU_CMD_SET_DDR_WTR	ADI_EBIU_TIMING_VALUE
Write recovery time	ADI_EBIU_CMD_SET_DDR_WR	ADI_EBIU_TIMING_VALUE

Upon successful initialization of the module, subsequent calls to `adi_ebiu_AdjustSDRAM` adjust the SDRAM refresh rate in the `EBIU_SDRRC` or `DDRCTL0` register to correspond with the given system clock frequency.

When multiple banks are used, the `ADI_EBIU_CMD_SET_SDRAM_BANK_SIZE` and `ADI_EBIU_CMD_SET_SDRAM_BANK_COL_WIDTH` command-value pairs must be specified for each bank.

If the system configuration makes use of low power (2.5 V) SDRAM, the following values also need to be initialized.

Description	Command	Value Type
Extended mode register enable	ADI_EBIU_CMD_SET_SDRAM_EMREN	ADI_EBIU_SDRAM_EMREN
Partial array self-refresh	ADI_EBIU_CMD_SET_SDRAM_PASR	ADI_EBIU_PASR
Temperature compensated self-refresh	ADI_EBIU_CMD_SET_SDRAM_TCSR	ADI_EBIU_SDRAM_TCSR

Additional command-value pairs can be passed to the `adi_ebiu_Init` function, which can also be passed to `adi_ebiu_Control`. See `adi_ebiu_Control` for a description of those additional command-value pairs.

The `adi_ebiu_Init` function should be called only once, prior to adjusting the power management settings, so that the SDRAM is adjusted according to changes in `SCLK`. Subsequent calls to the function are ignored.

Prototype

```
ADI_EBIU_RESULT adi_ebiu_Init(
        const ADI_EBIU_COMMAND_PAIR *ConfigData,
        const u16 Reserved
);
```

Arguments

ConfigData	Address of a table of command-value pairs as defined by "ADI_EBIU_COMMAND" on page 4-31 and "Command Value Enumerations" on page 4-38. The last command in the table must be the ADI_EBIU_CMD_END command.
Reserved	u16 value reserved for future use

Return Value

In debug mode, the returned values from calling adi_ebiu_Init to initialize SDRAM are:

ADI_EBIU_RESULT_BAD_COMMAND	Command-value pair is invalid.
ADI_EBIU_RESULT_FAILED	Not all required items are initialized.
ADI_EBIU_RESULT_ALREADY_INITIALIZED	EBIU module is already initialized.
ADI_EBIU_RESULT_INVALID_SDRAM_SCTLE	Invalid SCTLE value specified.
ADI_EBIU_RESULT_INVALID_SDRAM_MODULE	Invalid memory module type is specified.
ADI_EBIU_RESULT_INVALID_SDRAM_BANK_SIZE	Invalid bank size is specified.
ADI_EBIU_RESULT_INVALID_SDRAM_COL_WIDTH	Invalid column address width is specified.
ADI_EBIU_RESULT_INVALID_SDRAM_TWRMIN	Invalid TWRMIN value is specified.
ADI_EBIU_RESULT_INVALID_SDRAM_EMREN	Invalid EMREN value is specified.
ADI_EBIU_RESULT_INVALID_SDRAM_PASR	Invalid PASR value is specified.
ADI_EBIU_RESULT_INVALID_SDRAM_TCSR	Invalid TCSR value is specified.

In debug mode, the returned values from calling `adi_ebiu_Init` to initialize DDR are:

ADI_EBIU_RESULT_SUCCESS	Generic success
ADI_EBIU_RESULT_FAILED	Generic failure
ADI_EBIU_RESULT_BAD_COMMAND	Invalid control command
ADI_EBIU_RESULT_INVALID_DDR_MODULE	Invalid SDRAM module type
ADI_EBIU_RESULT_INVALID_DDR_REFI	Invalid auto-refresh interval
ADI_EBIU_RESULT_INVALID_DDR_RFC	Invalid auto-refresh command period
ADI_EBIU_RESULT_INVALID_DDR_RP	Invalid precharge to active interval
ADI_EBIU_RESULT_INVALID_DDR_RAS	Invalid active to precharge interval
ADI_EBIU_RESULT_INVALID_DDR_RC	Invalid active to active interval
ADI_EBIU_RESULT_INVALID_DDR_WTR	Invalid write to read interval
ADI_EBIU_RESULT_INVALID_DDR_DEVICE_SIZE	Invalid device size
ADI_EBIU_RESULT_INVALID_DDR_DEVICE_WIDTH	Invalid device width
ADI_EBIU_RESULT_INVALID_DDR_EXTERNAL_BANKS	Invalid number of external banks
ADI_EBIU_RESULT_INVALID_DDR_DATA_WIDTH	Invalid data width
ADI_EBIU_RESULT_INVALID_DDR_WR	Invalid write recovery time
ADI_EBIU_RESULT_INVALID_DDR_MRD	Invalid mode register selection
ADI_EBIU_RESULT_INVALID_DDR_RCD	Invalid active to R/W interval
ADI_EBIU_RESULT_INVALID_DDR_CAS	Invalid delay R/W to valid data
ADI_EBIU_RESULT_INVALID_DDR_PASR	Invalid partial array self-refresh request
ADI_EBIU_RESULT_INVALID_DDR_SOFT_RESET	Invalid soft reset request
ADI_EBIU_RESULT_INVALID_DDR_SELF_REFRESH_REQUEST	Invalid self-refresh request

`ADI_EBIU_RESULT_INVALID_DDR_MOBILE_DDR_ENABLE`	Invalid mobile DDR enable request
`ADI_EBIU_RESULT_ALREADY_INITIALIZED`	EBIU service already initialized

In debug mode, the returned values from calling `adi_ebiu_Init` to initialize the asynchronous memory controller are:

`ADI_EBIU_RESULT_SUCCESS`	Generic success
`ADI_EBIU_RESULT_FAILED`	Generic failure
`ADI_EBIU_RESULT_INVALID_ASYNCH_CLKOUT_ENABLE`	Invalid selection for `CLKOUT` enable
`ADI_EBIU_RESULT_INVALID_ASYNCH_BANK_ENABLE`	Invalid selection for bank enable
`ADI_EBIU_RESULT_INVALID_ASYNCH_BANK_NUMBER`	Invalid bank number specified in command argument
`ADI_EBIU_RESULT_INVALID_ASYNCH_BANK_16_BIT_PACKING_ENABLE`	For ADSP-BF561 only. Invalid specification for 16-bit packing enable
`ADI_EBIU_RESULT_INVALID_ASYNCH_BANK_TRANSITION_TIME`	Invalid transition time
`ADI_EBIU_RESULT_INVALID_ASYNCH_BANK_READ_ACCESS_TIME`	Invalid read access time
`ADI_EBIU_RESULT_INVALID_ASYNCH_BANK_WRITE_ACCESS_TIME`	Invalid write access time
`ADI_EBIU_RESULT_INVALID_ASYNCH_BANK_SETUP_TIME`	Invalid setup time
`ADI_EBIU_RESULT_INVALID_ASYNCH_BANK_HOLD_TIME`	Invalid hold time
`ADI_EBIU_RESULT_INVALID_ASYNCH_BANK_ARDY_ENABLE`	Invalid selection for `ARDY` enable
`ADI_EBIU_RESULT_INVALID_ASYNCH_BANK_ARDY_POLARITY`	Invalid selection for `ARDY` polarity
`ADI_EBIU_RESULT_ALREADY_INITIALIZED`	EBIU service already initialized

adi_ebiu_LoadConfig

Description

The adi_ebiu_LoadConfig function restores the current configuration values from the memory location pointed to by the hConfig argument. The SDRAM controller is reset.

Prototype

```
ADI_EBIU_RESULT adi_ebiu_LoadConfig(
                ADI_EBIU_CONFIG_HANDLE hConfig,
                size_t szConfig
);
```

Argument

hConfig	Address of the memory area where the current configuration is stored
szConfig	Number of bytes available at the given address. Must be greater than or equal to the adi_ebiu_GetConfigSize() return value.

Return Value

In the debug variant of the library, one of the following values is returned; otherwise, ADI_EBIU_RESULT_SUCCESS is returned.

ADI_EBIU_RESULT_SUCCESS	Process completed successfully.
ADI_EBIU_RESULT_NO_MEMORY	Value szConfig is too small.
ADI_EBIU_RESULT_NOT_INITIALIZED	SDRAM has not been successfully initialized.

adi_ebiu_SaveConfig

Description

The adi_ebiu_SaveConfig() function stores the current settings into the memory area pointed to by the hConfig argument. Currently, only the SDRAM configuration is saved.

Prototype

```
ADI_EBIU_RESULT adi_ebiu_SaveConfig(
                ADI_EBIU_CONFIG_HANDLE hConfig,
                size_t szConfig
);
```

Argument

hConfig	Address of the memory location where the current configuration is stored
szConfig	Number of bytes available at the given address. Must be greater than or equal to the adi_ebiu_GetConfigSize() return value.

Return Value

In the debug variant of the library, one of the following values is returned; otherwise, ADI_EBIU_RESULT_SUCCESS is returned.

ADI_EBIU_RESULT_SUCCESS	Process completed successfully.
ADI_EBIU_RESULT_NO_MEMORY	Value szConfig is too small.
ADI_EBIU_RESULT_NOT_INITIALIZED	SDRAM has not been successfully initialized.

Public Data Types and Enumerations

This section provides descriptions of the public data types and enumerations.

ADI_EBIU_RESULT

All public EBIU module functions return a result code of the enumeration type, ADI_EBIU_RESULT. Note that SDRAM-related result codes typically begin with the text ADI_EBIU_RESULT_INVALID_SDRAM while DDR-related result codes typically begin with the text ADI_EBIU_RESULT_INVALID_DDR. Table 4-2 lists possible values.

Table 4-2. EBIU Module Function Result Codes

Result Code	Explanation
ADI_EBIU_RESULT_SUCCESS	Generic success
ADI_EBIU_RESULT_FAILED	Generic failure
ADI_EBIU_RESULT_BAD_COMMAND	Invalid control command is specified.
ADI_EBIU_RESULT_NOT_INITIALIZED	Function call ignored with no action taken, as the module has not been initialized.
ADI_EBIU_RESULT_INVALID_SDRAM_EBE	Invalid value for the EBE field of the EBIU_SDBCTL register is specified.
ADI_EBIU_RESULT_INVALID_SDRAM_BANK_SIZE	Invalid value for the EBSZ field of the EBIU_SDBCTL register is specified.
ADI_EBIU_RESULT_INVALID_SDRAM_COL_WIDTH	Invalid value for the EBCAW field of the EBIU_SDBCTL register is specified.
ADI_EBIU_RESULT_INVALID_SDRAM_CDDBG	Invalid value for the CDDBG field of the EBIU_SDGCTL register is specified.

Table 4-2. EBIU Module Function Result Codes (Cont'd)

Result Code	Explanation
ADI_EBIU_RESULT_INVALID_SDRAM_EBUFE	Invalid value for the EBUFE field of the EBIU_SDGCTL register is specified.
ADI_EBIU_RESULT_INVALID_SDRAM_EMREN	Invalid value for the EMREN field of the EBIU_SDGCTL register is specified.
ADI_EBIU_RESULT_INVALID_SDRAM_FBBRW	Invalid value for the FBBRW field of the EBIU_SDGCTL register is specified.
ADI_EBIU_RESULT_INVALID_SDRAM_PASR	Invalid value for the PASR field of the EBIU_SDGCTL register is specified.
ADI_EBIU_RESULT_INVALID_SDRAM_PSM	Invalid value for the PSM field of the EBIU_SDGCTL register is specified.
ADI_EBIU_RESULT_INVALID_SDRAM_PUPSD	Invalid value for the PUPSD field of the EBIU_SDGCTL register is specified.
ADI_EBIU_RESULT_INVALID_SDRAM_SRFS	Invalid value for the SRFS field of the EBIU_SDGCTL register is specified.
ADI_EBIU_RESULT_INVALID_SDRAM_TCSR	Invalid value for the TCSR field of the EBIU_SDGCTL register is specified.
ADI_EBIU_RESULT_INVALID_SDRAM_TWRMIN	Invalid value for TWRMIN is specified and causes TWR to be greater than 3.
ADI_EBIU_RESULT_NO_MEMORY	Insufficient memory to load/save configuration.
ADI_EBIU_RESULT_INVALID_EZKIT	Invalid EZ-KIT revision
ADI_EBIU_RESULT_INVALID_SDRAM_SCTLE	Invalid SCTLE value
ADI_EBIU_RESULT_INVALID_SDRAM_MODULE	Invalid SDRAM module type

Table 4-2. EBIU Module Function Result Codes (Cont'd)

Result Code	Explanation
ADI_EBIU_RESULT_INVALID_IVG	Invalid IVG level supplemental interrupt (for dual-core processors only
ADI_EBIU_RESULT_INVALID_SDRAM_BANK	Invalid bank number given
ADI_EBIU_RESULT_INVALID_SDRAM_SCK1E	Invalid SCK1E value
ADI_EBIU_RESULT_INVALID_DDR_MODULE	Invalid SDRAM (DDR) module type
ADI_EBIU_RESULT_INVALID_DDR_REFI	Invalid refresh interval
ADI_EBIU_RESULT_INVALID_DDR_RFC	Invalid auto-refresh command
ADI_EBIU_RESULT_INVALID_DDR_RP	Invalid precharge to active interval
ADI_EBIU_RESULT_INVALID_DDR_RAS	Invalid active to precharge interval
ADI_EBIU_RESULT_INVALID_DDR_RC	Invalid active to active interval
ADI_EBIU_RESULT_INVALID_DDR_WTR	Invalid write to read interval
ADI_EBIU_RESULT_INVALID_DDR_DEVICE_SIZE	Invalid device size
ADI_EBIU_RESULT_INVALID_DDR_DEVICE_WIDTH	Invalid device width
ADI_EBIU_RESULT_INVALID_DDR_EXTERNAL_BANKS	Invalid number of external banks
ADI_EBIU_RESULT_INVALID_DDR_DATA_WIDTH	Invalid data width
ADI_EBIU_RESULT_INVALID_DDR_WR	Invalid write recovery time
ADI_EBIU_RESULT_INVALID_DDR_MRD	Invalid mode register selection
ADI_EBIU_RESULT_INVALID_DDR_RCD	Invalid active to R/W interval
ADI_EBIU_RESULT_INVALID_DDR_CAS	Invalid R/W to valid data interval
ADI_EBIU_RESULT_INVALID_DDR_PASR	Invalid partial array self-refresh request
ADI_EBIU_RESULT_INVALID_DDR_SOFT_RESET	Invalid soft reset request

Table 4-2. EBIU Module Function Result Codes (Cont'd)

Result Code	Explanation
ADI_EBIU_RESULT_INVALID_DDR_MOBILE_ENABLE	Invalid mobile DDR enable request
ADI_EBIU_RESULT_INVALID_DDR_SELF_REFRESH_REQUEST	Invalid self refresh request

ADI_EBIU_SDRAM_BANK_VALUE

The ADI_EBIU_SDRAM_BANK_VALUE structure specifies the settings that are applied to a specific bank.

```
typedef struct ADI_EBIU_SDRAM_BANK_VALUE (
        u16 bank;
        Union {
              ADI_EBIU_SDRAM_BANK_SIZE size;
              ADI_EBIU_SDRAM_BANK_COL_WIDTH width;
        } value;
} ADI_EBIU_SDRAM_BANK_VALUE;
```

See "ADI_EBIU_SDRAM_BANK_SIZE" on page 4-39 and "ADI_EBIU_SDRAM_BANK_COL_WIDTH" on page 4-39 for details of the size and width fields.

The bank field is intended for use only with Blackfin processors that have multiple SDRAM banks.

ADI_EBIU_TIME

The ADI_EBIU_TIME structure enables users to specify a timing value as an integral number of a given unit. It is defined as:

```
typedef struct ADI_EBIU_TIME {
      u32       value;
      ADI_EBIU_TIMING_UNIT units;
} ADI_EBIU_TIME;
```

where ADI_EBIU_TIMING_UNIT is an enumeration type defined as follows.

ADI_EBIU_TIMING_UNIT_MILLISEC	Time value specified by the associated value in the ADI_EBIU_TIME structure is in milliseconds (ms)
ADI_EBIU_TIMING_UNIT_MICROSEC	Time value specified by the associated value in the ADI_EBIU_TIME structure is in microseconds (ms)
ADI_EBIU_TIMING_UNIT_NANOSEC	Time value specified by the associated value in the ADI_EBIU_TIME structure is in nanoseconds (ns)
ADI_EBIU_TIMING_UNIT_PICOSEC	Time value specified by the associated value in the ADI_EBIU_TIME structure is in picoseconds (ps)
ADI_EBIU_TIMING_UNIT_FEMTOSEC	Time value specified by the associated value in the ADI_EBIU_TIME structure is in femtoseconds (fs)

The actual values of the enumeration fields are used as factors in the integer arithmetic within the module. The millisecond value, which is used as a logic control value, is an exception, since it is not used as a factor.

Developers can use the complete range of units to enable timing values to be expressed as an unsigned 32-bit integer. For example, the SDRAM on the ADSP-BF533 EZ-KIT Lite board has a minimum TWR value of one SCLK cycle and 7.5 ns. The time value must be passed as 7500 ps. Thus, the ADI_EBIU_TIME value must be specified as:

```
ADI_EBIU_TIME time = {7500, ADI_EBIU_TIMING_UNIT_PICOSEC};
```

ADI_EBIU_TIMING_VALUE

Certain timing values required to correctly set the SDRAM control registers are specified on the appropriate processor's data sheet as a number of SCLK cycles combined with a value expressed in one of several units (for example, nanoseconds or milliseconds).

To facilitate the passing of such values to the adi_ebiu_Init function, the ADI_EBIU_TIMING_VALUE structure is defined as:

```
typedef struct ADI_EBIU_TIMING_VALUE {
        u32    cycles;
        ADI_EBIU_TIME    time;
} ADI_EBIU_TIMING_VALUE;
```

where ADI_EBIU_TIME is defined in "ADI_EBIU_TIME" on page 4-27.

For example, the SDRAM on the ADSP-BF533 EZ-KIT Lite board has a minimum TWR value of one SCLK cycle and 7.5 ns. Using the above structure, this value is expressed as:

```
ADI_EBIU_TIMING_VALUE twrmin
         = { 1, {7500, ADI_EBIU_TIMING_UNIT_PICOSEC}};
```

ADI_EBIU_ASYNCH_BANK_TIMING

The asynchronous memory controller supports a number of different interfaces, therefore a structure is provided which allows the bank specific timing parameters to be specified either in cycles, or in timing units, *but not both*.

If the parameter is specified in cycles, the value is written directly to the register. If the value is specified in timing units, it is converted to cycles based on the presence of a 133 MHz system clock, and the converted value is written to the register.

Timing values used to set the asynchronous memory control registers should be derived from the appropriate data sheet for the type of memory device used.

The structure used to specify the timing parameters for the asynchronous memory interface is shown below. It contains two other structures: the enumeration "ADI_EBIU_BANK_NUMBER" on page 4-44 and the structure "ADI_EBIU_TIMING_VALUE" on page 4-28.

```
typedef struct ADI_EBIU_ASYNCH_BANK_TIMING
{
        ADI_EBIU_BANK_NUMBER        bank_number;
        ADI_EBIU_TIMING_VALUE       bank_time;
} ADI_EBIU_ASYNCH_BANK_TIMING;
```

ADI_EBIU_ASYNCH_BANK_VALUE

Because many of the EBIU parameters are bank specific, and specify a binary value such as `enabled` and `disabled`, a structure is provided which contains a bank number along with a union of three different enumerations that have two possible values.

The `ADI_EBIU_ASYNCH_BANK_VALUE` structure, shown below, is used for the `ARDY` polarity, which is either low or high. (See "ADI_EBIU_ASYNCH_BANK_ARDY_POLARITY" on page 4-46.) It is used for the `ARDY` enable, which is either enabled or disabled. (See "ADI_EBIU_ASYNCH_BANK_ARDY_ENABLE" on page 4-46.) It is also used for the 16-bit packing enable field (*for the ADSP-BF561 only*), which is either 16-bit packing enabled or 32-bit packing disabled. (See "ADI_EBIU_ASYNCH_BANK_DATA_PATH" on page 4-45.)

```
typedef struct ADI_EBIU_ASYNCH_BANK_VALUE
{
   u32 bank_number;
   union
   {
      ADI_EBIU_ASYNCH_BANK_ARDY_POLARITY       ardy_polarity;
      ADI_EBIU_ASYNCH_BANK_ARDY_ENABLE         ardy_enable;
#if defined(__ADSP_TETON__)
      ADI_EBIU_ASYNCH_BANK_DATA_PATH           data_path;
```

```
#endif
    } value;
} ADI_EBIU_ASYNCH_BANK_VALUE;
```

Setting Control Values in the EBIU Module

To set control values in the EBIU module, the user passes command-value pairs (of the type ADI_EBIU_COMMAND_PAIR) to the adi_ebiu_Init and adi_ebiu_Control functions (either individually or as a table). Note that adi_ebiu_Init only allows a table to be supplied. This section describes the command-value pair structure and valid commands.

ADI_EBIU_COMMAND

The ADI_EBIU_COMMAND is used to control/access the configuration of the EBIU module. It is used in an ADI_EBIU_COMMAND_PAIR couplet to set a configuration value in calls to adi_ebiu_Init and adi_ebiu_Control. Note that SDRAM-related commands typically begin with the text ADI_EBIU_CMD_SET_SDRAM while DDR-related commands typically begin with the text ADI_EBIU_CMD_SET_DDR.

Table 4-3. ADI_EBIU_COMMAND Data Values

Command	Associated Data Value
General commands used with both the adi_ebiu_Control and adi_ebiu_Init functions.	
ADI_EBIU_CMD_END	Defines the end of a table of command pairs.
ADI_EBIU_CMD_SET_SDRAM_EBUFE	ADI_EBIU_SDRAM_EBUFE value specifying whether external buffers are used when several SDRAM devices are used. See "ADI_EBIU_SDRAM_EBUFE" on page 4-42.

Table 4-3. ADI_EBIU_COMMAND Data Values (Cont'd)

Command	Associated Data Value
ADI_EBIU_CMD_SET_SDRAM_FBBRW	ADI_EBIU_SDRAM_FBBRW value specifying whether to enable/disable fast back-to-back read/write operations. See "ADI_EBIU_SDRAM_FBBRW" on page 4-43.
ADI_EBIU_CMD_SET_SDRAM_CDDBG	ADI_EBIU_SDRAM_CDDBG value specifying whether to enable/disable SDRAM control signals when the external memory interface is granted to an external controller. See "ADI_EBIU_SDRAM_CDDBG" on page 4-44.
ADI_EBIU_CMD_SET_SDRAM_PUPSD	ADI_EBIU_SDRAM_PUPSD value specifying whether the power-up start sequence is delayed by 15 SCLK cycles. See "ADI_EBIU_SDRAM_PUPSD" on page 4-42.
ADI_EBIU_CMD_SET_SDRAM_PSM	ADI_EBIU_SDRAM_PSM value specifying the order of events in the power-up start sequence. See "ADI_EBIU_SDRAM_PSM" on page 4-43.
ADI_EBIU_CMD_SET_ASYNCH_BANK_TRANSITION_TIME	ADI_EBIU_ASYNCH_BANK_TIMING value specifying an ADI_EBIU_BANK_NUMBER and an ADI_EBIU_TIMING_VALUE that specifies the transition time in either cycles or timing units. See "ADI_EBIU_ASYNCH_BANK_TIMING" on page 4-29.
ADI_EBIU_CMD_SET_ASYNCH_BANK_READ_ACCESS_TIME	ADI_EBIU_ASYNCH_BANK_TIMING value specifying an ADI_EBIU_BANK_NUMBER and an ADI_EBIU_TIMING_VALUE that specifies the read access time in either cycles or timing units. See "ADI_EBIU_ASYNCH_BANK_TIMING" on page 4-29.
ADI_EBIU_CMD_SET_ASYNCH_BANK_WRITE_ACCESS_TIME	ADI_EBIU_ASYNCH_BANK_TIMING value specifying an ADI_EBIU_BANK_NUMBER and an ADI_EBIU_TIMING_VALUE that specifies the write access time in either cycles or timing units. See "ADI_EBIU_ASYNCH_BANK_TIMING" on page 4-29.

Table 4-3. ADI_EBIU_COMMAND Data Values (Cont'd)

Command	Associated Data Value
ADI_EBIU_CMD_SET_ASYNCH_BANK_SETUP_TIME	ADI_EBIU_ASYNCH_BANK_TIMING value specifying an ADI_EBIU_BANK_NUMBER and an ADI_EBIU_TIMING_VALUE that specifies the setup time in either cycles or timing units. See "ADI_EBIU_ASYNCH_BANK_TIMING" on page 4-29.
ADI_EBIU_CMD_SET_ASYNCH_BANK_HOLD_TIME	ADI_EBIU_ASYNCH_BANK_TIMING value specifying an ADI_EBIU_BANK_NUMBER and an ADI_EBIU_TIMING_VALUE that specifies the hold time in either cycles or timing units. See "ADI_EBIU_ASYNCH_BANK_TIMING" on page 4-29.
Commands valid only when passed to the adi_ebiu_Init function.	
ADI_EBIU_CMD_SET_SDRAM_MODULE	ADI_EBIU_SDRAM_MODULE_TYPE value containing the configured Micron memory module. This value applies to all banks in use. See "ADI_EBIU_SDRAM_MODULE_TYPE" on page 4-39.
ADI_EBIU_CMD_SET_SDRAM_BANK_SIZE	Address of an ADI_EBIU_SDRAM_BANK_VALUE structure containing the bank number and the external bank size. Refer to "ADI_EBIU_SDRAM_BANK_VALUE" on page 4-27 and "ADI_EBIU_SDRAM_BANK_SIZE" on page 4-39.
ADI_EBIU_CMD_SET_SDRAM_BANK_COL_WIDTH	Address of an ADI_EBIU_SDRAM_BANK_VALUE structure containing the bank number and the external bank column address width. See "ADI_EBIU_SDRAM_BANK_VALUE" on page 4-27 and "ADI_EBIU_SDRAM_BANK_COL_WIDTH" on page 4-39.
ADI_EBIU_CMD_SET_SDRAM_CL_THRESHOLD	u32 value specifying the SCLK frequency threshold, which determines the CAS latency value to use.

Table 4-3. ADI_EBIU_COMMAND Data Values (Cont'd)

Command	Associated Data Value
ADI_EBIU_CMD_SET_SDRAM_TRASMIN	ADI_EBIU_TIME value setting the minimum TRAS value described in the appropriate Blackfin processor data sheet of the appropriate SDRAM. See "ADI_EBIU_TIME" on page 4-27.
ADI_EBIU_CMD_SET_SDRAM_TRPMIN	ADI_EBIU_TIME value setting the minimum TRP value as described in the appropriate Blackfin processor data sheet of the appropriate SDRAM. See "ADI_EBIU_TIME" on page 4-27.
ADI_EBIU_CMD_SET_SDRAM_TRCDMIN	ADI_EBIU_TIME value setting the minimum TRCD value as described in the appropriate Blackfin processor data sheet of the appropriate SDRAM. See "ADI_EBIU_TIME" on page 4-27.
ADI_EBIU_CMD_SET_SDRAM_TWRMIN	Address of an ADI_EBIU_TIMING_VALUE structure containing the minimum TWR value as described in the appropriate Blackfin processor data sheet of the appropriate SDRAM. See "ADI_EBIU_TIMING_VALUE" on page 4-28.
ADI_EBIU_CMD_SET_SDRAM_REFRESH	Address of an ADI_EBIU_TIMING_VALUE structure containing the maximum t_{REF} value described in the appropriate Blackfin processor data sheet of the appropriate SDRAM. See "ADI_EBIU_TIME" on page 4-27.
ADI_EBIU_CMD_SET_SDGCTL_REG	u32 word containing the entire contents of the EBIU_SDGCTL register
ADI_EBIU_CMD_SET_SDBCTL_REG	u16 word containing the entire contents of the EBIU_SDBCTL register
ADI_EBIU_CMD_SET_SDRAM_EMREN	ADI_EBIU_SDRAM_EMREN value specifying whether low power (2.5 V) SDRAM is used. See "ADI_EBIU_SDRAM_MODULE_TYPE" on page 4-39.

Table 4-3. ADI_EBIU_COMMAND Data Values (Cont'd)

Command	Associated Data Value
ADI_EBIU_CMD_SET_SDRAM_PASR	ADI_EBIU_SDRAM_PASR value specifying which banks are refreshed. Applicable only to low power SDRAM. See "ADI_EBIU_CMD_SET_SDRAM_SCTLE" on page 4-40.
ADI_EBIU_CMD_SET_SDRAM_TCSR	ADI_EBIU_SDRAM_TCSR value specifying the temperature-compensated, self-refresh value. This command can only be used for low power SDRAM. See "ADI_EBIU_SDRAM_PASR" on page 4-41.
ADI_EBIU_CMD_SET_SDRAM_SCTLE	ADI_EBIU_SDRAM_SCTLE value specifying whether the SDC is enabled. See "ADI_EBIU_CMD_SET_SDRAM_SCTLE" on page 4-40.
ADI_EBIU_CMD_SET_DDR_DATA_WIDTH	Set DDR width of data
ADI_EBIU_CMD_SET_DDR_EXTERNAL_BANKS	Set number of DDR external banks
ADI_EBIU_CMD_SET_DDR_DEVICE_WIDTH	Set DDR width of device
ADI_EBIU_CMD_SET_DDR_DEVICE_SIZE	Set size of device
ADI_EBIU_CMD_SET_DDR_REFI	Set DDR auto-refresh interval
ADI_EBIU_CMD_SET_DDR_RFC	Set auto-refresh command period
ADI_EBIU_CMD_SET_DDR_CAS	Set DDR CAS latency: cycles from R/W to first valid data
ADI_EBIU_CMD_SET_DDR_RCD	Set interval between active command and R/W assertion
ADI_EBIU_CMD_SET_DDR_RC	Set interval between successive DDR activate commands
ADI_EBIU_CMD_SET_DDR_RAS	Set DDR active to precharge interval
ADI_EBIU_CMD_SET_DDR_RP	Set DDR precharge to active interval
ADI_EBIU_CMD_SET_DDR_MRD	Set DDR interval between setting of mode register and next command
ADI_EBIU_CMD_SET_DDR_WTR	Set DDR interval between write and read command

Table 4-3. ADI_EBIU_COMMAND Data Values (Cont'd)

Command	Associated Data Value
ADI_EBIU_CMD_SET_DDR_WR	Set DDR write recovery time
ADI_EBIU_CMD_SET_DDR_PASR	Set DDR partial array self-refresh (mobile only) 0=full array, 1=half, 2=quarter, 5=eighth, 6=sixteenth
ADI_EBIU_CMD_SET_DDR_SOFT_RESET	Issue DDR soft reset
ADI_EBIU_CMD_MOBILE_DDR_ENABLE	Enable mobile DDR
ADI_EBIU_CMD_SET_FREQ_AS_MHZ	Sets DDR frequency units to megahertz
ADI_EBIU_CMD_SET_ASYNCH_BANK_ARDY_ENABLE	ADI_EBIU_ASYNCH_BANK_VALUE specifying a bank number and an ADI_EBIU_ASYNCH_BANK_ARDY_ENABLE that specifies whether the ARDY input will be sampled for this bank. See "ADI_EBIU_ASYNCH_BANK_ARDY_ENABLE" on page 4-46.
ADI_EBIU_CMD_SET_ASYNCH_BANK_ARDY_POLARITY	ADI_EBIU_ASYNCH_BANK_VALUE specifying a bank number and an ADI_EBIU_ASYNCH_BANK_ARDY_POLARITY that specifies the polarity of the ARDY input sample that indicates the completion of the access time. See "ADI_EBIU_ASYNCH_BANK_ARDY_POLARITY" on page 4-46.
ADI_EBIU_CMD_SET_ASYNCH_BANK_16_BIT_PACKING_ENABLE	*For ADSP-BF561 processors only* ADI_EBIU_ASYNCH_BANK_VALUE specifying a bank number and an ADI_EBIU_ASYNCH_BANK_DATA_PATH that specifies whether or not 16-bit packing is enabled. See "ADI_EBIU_ASYNCH_BANK_DATA_PATH" on page 4-45.
ADI_EBIU_CMD_SET_ASYNCH_BANK_ENABLE	ADI_EBIU_ASYNCH_BANK_ENABLE value specifying which banks to enable. See "ADI_EBIU_ASYNCH_BANK_ENABLE" on page 4-45.

Table 4-3. ADI_EBIU_COMMAND Data Values (Cont'd)

Command	Associated Data Value
ADI_EBIU_CMD_SET_ASYNCH_CLKOUT_ENABLE	ADI_EBIU_ASYNCH_CLKOUT value specifying whether to enable or disable CLKOUT in the asynchronous global control register. See "ADI_EBIU_ASYNCH_CLKOUT" on page 4-45.
ADI_EBIU_CMD_SET_ASYNCH_AMGCTL	16-bit numeric value used to simultaneously set all the fields of the asynchronous memory global control register
ADI_EBIU_CMD_SET_ASYNCH_AMBCTL0	32-bit numeric value used to simultaneously set all the fields of the asynchronous memory bank control register 0 at once
ADI_EBIU_CMD_SET_ASYNCH_AMBCTL1	32-bit numeric value used to simultaneously set all the fields of the asynchronous memory bank control register 1 at once
Commands valid only when passed to the adi_ebiu_Control function.	
ADI_EBIU_CMD_PAIR	Used to tell adi_ebiu_control that a single command pair is being passed.
ADI_EBIU_CMD_TABLE	Used to tell adi_ebiu_control that a table of command pairs is being passed.
ADI_EBIU_CMD_SET_SDRAM_ENABLE	ADI_EBIU_SDRAM_ENABLE value enabling/disabling external SDRAM. Automatically set upon initialization. See "ADI_EBIU_SDRAM_ENABLE" on page 4-38.
ADI_EBIU_CMD_SET_SDRAM_SRFS	ADI_EBIU_SDRAM_SRFS value enabling/disabling self-refresh of SDRAM during inactivity. See "ADI_EBIU_SDRAM_TCSR" on page 4-41.
ADI_EBIU_CMD_DDR_SELF_REFRESH_REQUEST	Request DDR self-refresh

ADI_EBIU_COMMAND_PAIR

The `ADI_EBIU_COMMAND_PAIR` data type enables developers to generate a table of control commands to pass to the EBIU via the `adi_ebiu_Init` and `adi_ebiu_Control` functions:

```
typedef struct ADI_EBIU_COMMAND_PAIR (
        ADI_EBIU_COMMAND kind;
        void *value;
} ADI_EBIU_COMMAND_PAIR;
```

Command Value Enumerations

The following enumerations are used to specify the required information to set up the SDRAM controller. For further information on the values required, refer to *Engineer-to-Engineer Note EE-210*[1].

ADI_EBIU_SDRAM_ENABLE

This enumeration specifies if SDRAM is enabled or disabled. This enumeration corresponds to the `EBE` bit in the `EBIU_SDBCTL` register.

`ADI_EBIU_SDRAM_EBE_DISABLE`	Disables SDRAM.
`ADI_EBIU_SDRAM_EBE_ENABLE`	Enables SDRAM.

The default value is specified by the following macro:

```
#define ADI_EBIU_SDRAM_EBE_DEFAULT ADI_EBIU_SDRAM_EBE_DISABLE
```

[1] Refer to *SDRAM Selection Guidelines and Configuration for ADI Processors*, EE-210, October 27, 2003.

ADI_EBIU_SDRAM_BANK_SIZE

This enumeration specifies the SDRAM external bank size. This enumeration corresponds to the EBSZ bits in the EBIU_SDBCTL register.

ADI_EBIU_SDRAM_BANK_16MB	16MB external SDRAM
ADI_EBIU_SDRAM_BANK_32MB	32MB external SDRAM
ADI_EBIU_SDRAM_BANK_64MB	6 4MB external SDRAM
ADI_EBIU_SDRAM_BANK_128MB	128MB external SDRAM

The default value is specified by the following macro:

```
#define ADI_EBIU_SDRAM_BANK_SIZE_DEFAULT
ADI_EBIU_SDRAM_BANK_32MB
```

ADI_EBIU_SDRAM_BANK_COL_WIDTH

This enumeration specifies the SDRAM external bank column address width and corresponds to the EBCAW bits in the EBIU_SDBCTL register.

ADI_EBIU_SDRAM_BANK_COL_8BIT	8-bit external bank column address width
ADI_EBIU_SDRAM_BANK_COL_9BIT	9-bit external bank column address width
ADI_EBIU_SDRAM_BANK_COL_10BIT	10-bit external bank column address width
ADI_EBIU_SDRAM_BANK_COL_11BIT	11-bit external bank column address width

The default value is specified by the following macro:

```
#define ADI_EBIU_SDRAM_BANK_COL_WIDTH_DEFAULT
ADI_EBIU_SDRAM_BANK_COL_9BIT
```

ADI_EBIU_SDRAM_MODULE_TYPE

This enumeration specifies an SDRAM module type when the command ADI_EBIU_CMD_SET_SDRAM_MODULE is used to initialize the SDRAM controller. The enumerator values contain relevant module information such as the speed grade and configuration settings. The external memory bank size must also be specified using the ADI_EBIU_CMD_SET_SDRAM_BANK_SIZE command. Because Analog Devices EZ-KIT Lite boards include SDRAM supplied by Micron, this information applies only to Micron parts. The list of valid enumeration values are found in the API header file, adi_pwr.h.

ADI_EBIU_CMD_SET_SDRAM_SCTLE

This enumeration specifies if the SDRAM controller is enabled or disabled and corresponds to the SCTLE bit in the EBIU_SDGCTL register.

ADI_EBIU_SDRAM_SCTLE_DISABLE	Disable SDRAM controller.
ADI_EBIU_SDRAM_SCTLE_ENABLE	Enable SDRAM controller.

ADI_EBIU_SDRAM_EMREN

This enumeration specifies that low power (2.5 V) SDRAM is used and corresponds to the EMREN bit in the EBIU_SDGCTL register.

ADI_EBIU_SDRAM_EMREN_DISABLE	Mobile low power SDRAM is not present.
ADI_EBIU_SDRAM_EMREN_ENABLE	Mobile low power SDRAM is present.

The default value is specified by the following macro:

```
#define ADI_EBIU_SDRAM_EMREN_DEFAULT
ADI_EBIU_SDRAM_EMREN_DISABLE
```

ADI_EBIU_SDRAM_PASR

When low power (2.5 V) SDRAM is used, this enumeration specifies the banks to refresh. This enumeration corresponds to the PASR bits in the EBIU_SDGCTL register.

ADI_EBIU_SDRAM_PASR_ALL	All four SDRAM banks are refreshed.
ADI_EBIU_SDRAM_PASR_INT01	Internal SDRAM banks 0 and 1 are refreshed.
ADI_EBIU_PASR_INT0_ONLY	Only internal bank 0 is refreshed.

The default value is specified by the following macro:

```
#define ADI_EBIU_SDRAM_PASR_DEFAULT ADI_EBIU_SDRAM_PASR_ALL
```

ADI_EBIU_SDRAM_TCSR

When low power (2.5 V) SDRAM is used, this enumeration specifies the temperature-compensated, self-refresh value and corresponds to the TCSR bits in the EBIU_SDGCTL register.

ADI_EBIU_SDRAM_TCSR_45DEG	SDRAM banks are refreshed if the temperature exceeds 45° C.
ADI_EBIU_SDRAM_TCSR_85DEG	SDRAM banks are refreshed if the temperature exceeds 85° C.

The default value is specified by the following macro:

```
#define ADI_EBIU_SDRAM_TCSR_DEFAULT ADI_EBIU_SDRAM_TCSR_45DEG
```

ADI_EBIU_SDRAM_SRFS

This enumeration specifies whether the EBIU is to enable/disable SDRAM self-refresh during periods of inactivity. This enumeration corresponds to the SRFS bit in the EBIU_SDGCTL register.

For example, SDRAM self-refresh is enabled when the processor mode is put into "deep sleep" via the power management module. For more information, see "Power Management Module" on page 3-1.

ADI_EBIU_SDRAM_SRFS_DISABLE	Disables SDRAM self-refresh on inactivity.
ADI_EBIU_SDRAM_SRFS_ENABLE	Enables SDRAM self-refresh on inactivity.

The default value is specified by the following macro:

```
#define ADI_EBIU_SDRAM_SRFS_DEFAULT
ADI_EBIU_SDRAM_SRFS_DISABLE
```

ADI_EBIU_SDRAM_EBUFE

This enumeration specifies whether the EBIU uses external buffers when several SDRAM devices are used in parallel. This enumeration corresponds to the EBUFE bit in the EBIU_SDGCTL register.

ADI_EBIU_SDRAM_EBUFE_DISABLE	Disables the use of external buffers when several SDRAM devices are used in parallel.
ADI_EBIU_SDRAM_EBUFE_ENABLE	Enables the use of external buffers when several SDRAM devices are used in parallel.

The default value is specified by the following macro:

```
#define ADI_EBIU_SDRAM_EBUFE_DEFAULT
ADI_EBIU_SDRAM_EBUFE_DISABLE
```

ADI_EBIU_SDRAM_PUPSD

This enumeration specifies whether the power-up start sequence is delayed by 15 SCLK cycles. This enumeration corresponds to the PUPSD bit in the EBIU_SDGCTL register.

ADI_EBIU_SDRAM_PUPSD_NODELAY	No delay to the power-up start sequence.
ADI_EBIU_SDRAM_PUPSD_15CYCLES	Power-up start sequence is delayed by 15 SCLK cycles.

The default value is specified by the following macro:

```
#define ADI_EBIU_SDRAM_PUPSD_DEFAULT
ADI_EBIU_SDRAM_PUPSD_NODELAY
```

ADI_EBIU_SDRAM_PSM

This enumeration specifies the SDRAM power-up sequence. This enumeration corresponds to the PSM bit in the EBIU_SDGCTL register.

ADI_EBIU_SDRAM_PSM_REFRESH_FIRST	SDC performs a Precharge All command, followed by eight auto-refresh cycles, and then a Load Mode Register command.
ADI_EBIU_SDRAM_PSM_REFRESH_LAST	SDC performs a Precharge All command, followed by a Load Mode Register command, and then completes eight auto-refresh cycles.

The default value is specified by the following macro:

```
#define ADI_EBIU_SDRAM_PSM_DEFAULT
ADI_EBIU_SDRAM_PSM_REFRESH_FIRST
```

ADI_EBIU_SDRAM_FBBRW

This enumeration specifies whether the EBIU uses fast back-to-back, read-write access to allow SDRAM read and write operations on consecutive cycles. This enumeration corresponds to the FBBRW bit in the EBIU_SDGCTL register.

ADI_EBIU_SDRAM_FBBRW_DISABLE	Fast back-to-back, read-write access disabled.
ADI_EBIU_SDRAM_FBBRW_ENABLE	SDRAM read and write operations occur on consecutive cycles.

The default value is specified by the following macro:

```
#define ADI_EBIU_SDRAM_FBBRW_DEFAULT
ADI_EBIU_SDRAM_FBBRW_DISABLE
```

ADI_EBIU_SDRAM_CDDBG

This enumeration enables or disables the SDRAM control signals when the external memory interface is granted to an external controller. This enumeration corresponds to the `CDDBG` bit in the `EBIU_SDGCTL` register.

`ADI_EBIU_SDRAM_CDDBG_DISABLE`	Disables the SDRAM control signals when the external memory interface is granted to an external controller.
`ADI_EBIU_SDRAM_CDDBG_ENABLE`	Enables the SDRAM control signals when the external memory interface is granted to an external controller.

The default value is specified by the following macro:

```
#define ADI_EBIU_SDRAM_CDDBG_DEFAULT
ADI_EBIU_SDRAM_CDDBG_DISABLE
```

ADI_EBIU_BANK_NUMBER

This enumeration is used to specify the bank number 0, 1, 2, or 3, for which the associated command applies. It can also be used to specify all banks.

`ADI_EBIU_BANK_0`	Command is for bank 0.
`ADI_EBIU_BANK_1`	Command is for bank 1.
`ADI_EBIU_BANK_2`	Command is for bank 2.
`ADI_EBIU_BANK_3`	Command is for bank 3.
`ADI_EBIU_BANK_ALL`	Command is for ALL four banks.

ADI_EBIU_ASYNCH_BANK_ENABLE

This enumeration specifies which banks are being enabled. It corresponds to the AMBEN bits in the asynchronous memory global control register.

ADI_EBIU_ASYNCH_DISBALE_ALL	Disables all banks.
ADI_EBIU_ASYNCH_BANK0	Enables bank 0.
ADI_EBIU_ASYNCH_BANK0_1	Enables banks 0 and 1.
ADI_EBIU_ASYNCH_BANK0_1_2	Enables banks 0, 1, and 2.
ADI_EBIU_ASYNCH_BANK0_1_2_3	Enables all banks.

ADI_EBIU_ASYNCH_CLKOUT

This enumeration specifies whether CLKOUT is enabled for external memory access. It corresponds to the AMCKEN bits in the asynchronous memory global control register.

ADI_EBIU_ASYNCH_CLKOUT_DISABLE	CLKOUT is disabled.
ADI_EBIU_ASYNCH_CLKOUT_ENABLE	CLKOUT is enabled.

ADI_EBIU_ASYNCH_BANK_DATA_PATH

This enumeration is for the ADSP-BF561 only. It specifies whether 16-bit packing is enabled on the asynchronous memory bus. It corresponds to the BXPEN bits in the asynchronous memory global control register, where X is the bank number.

ADI_EBIU_ASYNCH_BANK_DATA_PATH_32	16-bit packing in NOT enabled.
ADI_EBIU_ASYNCH_BANK_DATA_PATH_16	16-bit packing is enabled.

ADI_EBIU_ASYNCH_BANK_ARDY_ENABLE

Each asynchronous bank can be programmed to sample the ARDY input, which allows the bank access time to be extended. Sampling the ARDY pin determines how long to extend the access time. This enumeration specifies whether or not the ARDY signal will be sampled. It corresponds to the BXRDYEN bit (where X is the bank number) in the asynchronous memory bank control 0 register (for banks 0 and 1) or the asynchronous memory bank control 1 register (for banks 2 and 3).

ADI_EBIU_ASYNCH_ARDY_DISABLE	Sampling of ARDY is disabled.
ADI_EBIU_ASYNCH_ARDY_ENABLE	Sampling of ARDY is enabled.

ADI_EBIU_ASYNCH_BANK_ARDY_POLARITY

This enumeration specifies, if ARDY is enabled, whether the access time is complete when the ARDY signal is low or high. It corresponds to the BXRDYPOL bit (where X is the bank number) in the asynchronous memory bank control 0 register (for banks 0 and 1) or the asynchronous memory bank control 1 register (for banks 2 and 3).

ADI_EBIU_ASYNCH_ARDY_POLARITY_LOW	Transaction is complete if ARDY is low.
ADI_EBIU_ASYNCH_ARDY_POLARITY_HIGH	Transaction is complete if ARDY is high.

ADI_EBIU_ASYNCH_HOLD_TIME

The hold time for the asynchronous memory controller is specified in the bank_time field of an "ADI_EBIU_ASYNCH_BANK_TIMING" structure. That field is of type "ADI_EBIU_TIMING_VALUE", which in this case can either specify a number of cycles or an "ADI_EBIU_TIME" value, *but not both*. When cycles are used, the ADI_EBIU_ASYNCH_HOLD_TIME enumeration specifies the number of cycles of hold time. It corresponds to the BXHT bit (where X is the bank number) in the asynchronous memory bank control 0 register (for banks 0 and 1) or the asynchronous memory bank control 1 register (for banks 2 and 3).

ADI_EBIU_ASYNCH_HT_0_CYCLES	0 cycles hold time
ADI_EBIU_ASYNCH_HT_1_CYCLES	1 cycles hold time
ADI_EBIU_ASYNCH_HT_2_CYCLES	2 cycles hold time
ADI_EBIU_ASYNCH_HT_3_CYCLES	3 cycles hold time

ADI_EBIU_ASYNCH_SETUP_TIME

The setup time for the asynchronous memory controller is specified in the bank_time field of an "ADI_EBIU_ASYNCH_BANK_TIMING" structure. That field is of type "ADI_EBIU_TIMING_VALUE", which in this case can either specify a number of cycles or an "ADI_EBIU_TIME" value, *but not both*. When cycles are used, the ADI_EBIU_ASYNCH_SETUP_TIME enumeration specifies the number of cycles of setup time. It corresponds to the BXST bit (where X is the bank number) in the asynchronous memory bank control 0 register (for banks 0 and 1) or the asynchronous memory bank control 1 register (for banks 2 and 3).

ADI_EBIU_ASYNCH_ST_4_CYCLES	4 cycles setup time
ADI_EBIU_ASYNCH_ST_1_CYCLES	1 cycles setup time
ADI_EBIU_ASYNCH_ST_2_CYCLES	2 cycles setup time
ADI_EBIU_ASYNCH_ST_3_CYCLES	3 cycles setup time

ADI_EBIU_ASYNCH_TRANSITION_TIME

The transition time for the asynchronous memory controller is specified in the bank_time field of an "ADI_EBIU_ASYNCH_BANK_TIMING" structure. That field is of type "ADI_EBIU_TIMING_VALUE", which in this case can either specify a number of cycles or an "ADI_EBIU_TIME" value, *but not both*. When cycles are used, the ADI_EBIU_ASYNCH_TRANSITION_TIME enumeration specifies the number of cycles of transition time. It corresponds to the BXHT bit (where X is the bank number) in the asynchronous memory bank control 0 register (for banks 0 and 1) or the asynchronous memory bank control 1 register (for banks 2 and 3).

ADI_EBIU_ASYNCH_TT_4_CYCLES	4 cycles transition time
ADI_EBIU_ASYNCH_TT_1_CYCLES	1 cycles transition time
ADI_EBIU_ASYNCH_TT_2_CYCLES	2 cycles transition time
ADI_EBIU_ASYNCH_TT_3_CYCLES	3 cycles transition time

5 DEFERRED CALLBACK MANAGER

This chapter describes the deferred callback (DCB) manager used by the application developer to manage the deferred execution of function calls. A detailed description of the application programming interface (API) provided by the deferred callback manager is included.

This chapter contains:

Introduction

Callback functions are commonly used in event-driven applications where the client application requests that a service manager (such as the system services library's (SSL) DMA manager) notifies it upon completion of a requested task, for example the completion of DMA transfer, by means of a *client callback function* specified by the client application upon initialization of the required service.

The need to execute a client callback function normally occurs while executing an interrupt service routine (ISR) at relatively high priority. The general rule for such ISRs is to keep the amount of time spent in them as deterministic as possible and to a minimum. Callbacks, on the other hand, may be lengthy and non-deterministic. In most cases, users may prefer to defer the execution of such callbacks to a scheduler running at a lower priority, which can be preempted by higher priority interrupts. In doing so, the requesting ISR can complete with minimal delay.

The system services library's deferred callback manager provides this service by managing one or more queues of deferred callbacks, such that their invocation typically occurs within a dispatch function operating at a lower-interrupt priority than the rest of the application's interrupt services. Each callback entry posted to a queue comprises the address of the required callback function along with three values (two pointers and one 32-bit unsigned integer), which are passed to the callback function upon its (deferred) execution.

The deferred callback (DCB) manager is designed to operate as a standalone module or in conjunction with a real-time operating system (RTOS). Implementations of the module exist for Express Logic's ThreadX, Green Hills Software' INTEGRITY, as well as Analog Devices VDK.

The number of queues available and their length is determined by the client application upon module and queue initialization. Whether the DCB manager is implemented in standalone mode or in conjunction with one of the above RTOSs also impacts the number and size of queues. When implemented in conjunction with VDK, the DCB manager can support only one queue at a fixed-priority level of IVG 14.

While only one queue is permitted per IVG level, engineers can set priorities for individual callback entries by supplying a software priority level upon posting. There is no limit to the number of software priority levels that can be used (except for practical implications within the limits of unsigned short values) The dispatch function attempts to execute all higher-priority callbacks before those with lower priorities at the same IVG level.

A detailed description of how the DCB manager operates is provided in "Using the Deferred Callback Manager" on page 5-3, along with code segments illustrating its use in standalone mode.Implications for its use in conjunction with an RTOS are given in "Interoperability With an RTOS" on page 5-8.

The DCB manager uses an unambiguous naming convention to safeguard against conflicts with other software libraries provided by ADI or other companies. As a result, all enumeration values and `typedef` statements use the `ADI_DCB_` prefix, and functions and global variables use the lowercase `adi_dcb_` equivalent.

Using the Deferred Callback Manager

The operation of the DCB manager comprises the following functions.

- Setting up the DCB manager
    - Initializing the DCB manager
    - Opening a queue
- Managing the queue
    - Posting callbacks to the required queue
    - Dispatching callbacks according to the priority level determined upon posting
- Performing housekeeping functions
    - Closing the queue
    - Terminating the DCB manager

How this is implemented depends on whether the DCB manager is used in standalone mode or in conjunction with the deferred calling mechanism supplied by an RTOS. In all cases, API calls to the DCB manager are the same: a queue is initialized with a call to `adi_dcb_Open`, and callbacks are added to the queue via a call to the `adi_dcb_Post` function.

The deferred execution of the callbacks is scheduled according to software priority by the `adi_dcb_Dispatch_Callbacks` function. In a standalone environment, the DCB manager registers this function as an interrupt handler routine against the desired IVG level, using the system services library's interrupt manager module, when the queue is initialized, and an interrupt raised each time a callback is posted. Since the standalone version uses the interrupt manager, the interrupt manager must be initialized before the DCB manager is initialized.

The following code sample demonstrates the standalone use of one queue initialized at IVG level 14, which is the lowest IVG level available at application level.

As mentioned above, standalone operation requires the initialization of the interrupt manager prior to initializing the DCB manager. On the assumption that the sample application requires that only one interrupt handler be defined per IVG level, initialize the interrupt manager with the following code:

```
u32 ne;
adi_int_Init(NULL,0,&ne,NULL);
```

Initialize the DCB manager with sufficient memory for one queue as follows:

```
static char mjk_dcb_Data[ADI_DCB_QUEUE_SIZE];
:
u32 ns;
:
adi_dcb_Init(
    (void*)mjk_dcb_Data,    // Address of memory to be used
    ADI_DCB_QUEUE_SIZE,     // Number of bytes required for the
                            // required number of queue servers.
    &ns                     // on return this should be the same
                            // as the required number of queues.
    NULL                    // No special data area for critical
                            // region required
);
```

Next, open the queue server for use by passing sufficient memory for the length of queue required (in this case, five entries) and the desired IVG level at which the queue operates. This level is ignored when used in a VDK-based application. A handle, `p_DCB_handle`, to the queue server is returned:

```
static char mjk_dcb_QueueData[5*ADI_DCB_ENTRY_SIZE];
ADI_DCB_HANDLE p_DCB_handle;
:
u32 nqe;
:
adi_dcb_Open(
    14,                          // required IVG level
    (void*) mjk_dcb_QueueData,   // Address of memory to be used
    5*ADI_DCB_ENTRY_SIZE,        // for a queue 5 deep.
    &nqe;                        // on return this should be the
                                 // same as the required number of
```

```
                                // entries (5 in this case).
    &p_DCB_handle               // returned handle to queue server
    );
```

The DCB manager is now ready to accept callback postings to the queue server. Note that this function is normally performed in an ISR of another service. The DCB manager passes the address of the client callback function and its associated argument values to the queue server identified by the handle obtained:

```
adi_dcb_Post(
    p_DCB_handle,         // handle to required queue server.
    0,                    // Priority level.
    ClientCallback,       // Address of callback function.
    pService,             // Address of the service instance
                          // that is posting the callback.
    event,                // Flag identifying the event that
                          // has precipitated the interrupt.
    (void*)data           // Address of data relevant to the
                          // callback.
);
```

In the example above, `event` typically defines an event (for example, DMA completion) and `data` typically points to an appropriate location in memory that is meaningful within the context of the callback function. Within the DMA manager context, this argument is the address of an appropriate descriptor or data buffer.

For any reason, flushing the queue of entries for the above callback can be achieved in one of two ways: by calling the `adi_dcb_Remove` function directly or by calling it indirectly using the `adi_dcb_Control` function.

See “adi_dcb_Terminate” for further details and an example of its use along with any other requests. The following code describes the direct approach:

```
adi_dcb_Remove(
    p_DCB_handle,            // handle to required queue server
    ClientCallback           // Address of callback function to
                             // flush
);
```

Finally, if required, the queue can be closed and the DCB manager terminated:

```
adi_dcb_Close(
    p_DCB_handle,        // handle to required queue server
);
adi_dcb_Terminate();
```

Interoperability With an RTOS

The DCB manager employs two functions, adi_dcb_RegisterISR and adi_dcb_Forward, to interface with the different RTOS environments, including standalone mode.

These functions are supplied in a separate source file, adi_dcb_xxxx.c, for each implementation where xxxx describes the required RTOS (for example, threadx for Express Logic's ThreadX, and integrity for Green Hill Software's INTEGRITY), or standalone for standalone use. VDK support is achieved with the functions (described above) supplied directly by VDK. As a result, there is no equivalent adi_dcb_vdk.c file.

The relevant adi_dcb_xxxx.c file is incorporated (or not) into the main adi_dcb.c source file via conditional compilation governed by a macro, ADI_SSL_XXXX, where XXXX is STANDALONE, THREADX, INTEGRITY, or VDK.

Currently, implementations of the DCB manager are provided only for the environments previously described. To implement these functions under an alternative RTOS (for example, Linux), developers must provide replacement definitions in equivalent files.

These functions are described in this section in more detail.

adi_dcb_Forward

The adi_dcb_Forward function takes two arguments. The first is a pointer to the DCB entry header structure, ADI_DCB_ENTRY_HDR, and the second is to the IVG level of the appropriate queue.

The adi_dcb_Forward function is invoked from within the adi_dcb_Post function and has the following prototype:

```
void adi_dcb_Forward(
     ADI_DCB_ENTRY_HDR *Entry,
     u16 IvgLevel
     );
```

The arguments are as follows.

Entry	Pointer to the ADI_DCB_ENTRY_HDR structure. This coincides with the address of the queue server structure to which the callback is posted. This is ignored in standalone mode.
IvgLevel	IVG level of the appropriate queue. This argument is ignored by VDK.

The ADI_DCB_ENTRY_HDR structure used to pass information to the underlying RTOS is defined as:

```
typedef struct ADI_DCB_ENTRY_HDR {
        struct ADI_DCB_ENTRY_HDR *pNext;
        ADI_DCB_DEFERRED_FNpDeferredFunction;
} ADI_DCB_ENTRY_HDR;
```

The first word in this structure, pNext, is NULL on entry to the adi_dcb_Forward function. While this value is typically used to point to the next item in the queue, its interpretation within the adi_dcb_Forward function depends on the specific RTOS implementation required. The second word, pDeferredFunction, is set to point to the adi_dcb_DispatchCallbacks function when the queue is initialized. The deferred procedure call server within the appropriate RTOS must pass the pointer to the adi_dcb_DispatchCallbacks function upon its deferred execution.

adi_dcb_RegisterISR

The adi_dcb_RegisterISR function is invoked from within the adi_dcb_Open function and has the following prototype:

```
void adi_dcb_RegisterISR(
     u16 IvgLevel,
     ADI_INT_HANDLER_FN Dispatcher,
     ADI_DCB_HANDLE *hServer
     );
```

The data types are defined in the <services/services.h> header file and the arguments are as follows.

IvgLevel	Interrupt level at which callbacks are dispatched
Dispatcher	Mandatory address of the adi_dcb_DispatchCallbacks function
hServer	Address of the queue server structure

In the standalone implementation, this function registers the adi_dcb_DispatchCallbacks function with the interrupt manager at the specified interrupt level. In the VDK implementation, it returns with no effect.

Handling Critical Regions Within Callbacks

If critical regions are required within a callback function, you must be aware of any restrictions imposed by the underlying RTOS. For example, VDK-based applications are prohibited from calling PushCriticalRegion/PopCriticalRegion functions from within the interrupt level.

If the VDK version of the DCB manager is used, these kinds of calls can be used, as the callback is executed at the kernel level. However, if the standalone version of the library is used to run a DCB queue at a higher priority than the VDK DPC queue, such calls are illegal since the callback executes at the interrupt level. In these cases, they effect critical regions directly by using the `cli()` and `sti()` built-in functions.

DCB Manager API Reference

This section provides descriptions of the DCB manager API functions.

Notation Conventions

The reference pages for the API functions use the following format:

Name – Name and purpose of the function

Description – Function specification

Prototype – Required header file and functional prototype

Arguments – Description of function arguments

Return Value – Description of function return values

adi_dcb_Close

Description

The `adi_dcb_Close()` function closes the DCB queue server identified by the single handle argument, freeing up the slot for subsequent use.
In standalone mode, the DCB manager's `adi_dcb_DispatchCallbacks` function is unhooked from the interrupt handler chain for the given IVG level.

Prototype

```
ADI_DMA_RESULT adi_dcb_Close(
        ADI_DCB_HANDLE hServer
);
```

Arguments

`hServer`	Handle of the required queue server to close

Return Value

In debug mode, this routine returns `ADI_DCB_RESULT_NO_SUCH_QUEUE` when the handle provided does not represent a valid queue server registered with the DCB manager; otherwise, `ADI_DCB_RESULT_SUCCESS` is returned.

`ADI_DCB_RESULT_SUCCESS`	Queue successfully closed.
`ADI_DCB_RESULT_NO_SUCH_QUEUE`	Handle provided does not represent a valid queue server.
`ADI_DCB_RESULT_QUEUE_IN_USE`	Callbacks are on the queue awaiting dispatch. If this does not matter, then flush the queue first before closing.

adi_dcb_Control

Description

The adi_dcb_Control() function is used to configure/control a deferred callback queue server according to command-value pairs. For more information, see "ADI_DCB_COMMAND_PAIR" on page 5-25.

Currently, only one command is relevant, ADI_DCB_CMD_FLUSH_QUEUE, though others may be added in the future. The command-value pairs can be specified in one of three ways:

- A single command-value pair is passed.

```
adi_dcb_Control(
        hServer,
        ADI_DCB_CMD_FLUSH_QUEUE,
        (void*)ClientCallback
);
```

- A single command-value pair structure is passed.

```
ADI_DCB_COMMAND_PAIR cmd=
        {ADI_DCB_CMD_FLUSH_QUEUE, (void *)ClientCallback};
adi_dcb_Control(
        hServer,
        ADI_DCB_CMD_PAIR,
        (void*)&cmd
);
```

- A table of ADI_DCB_COMMAND_PAIR structures is passed. The last entry in the table must be ADI_DCB_CMD_END.

```
ADI_DCB_COMMAND_PAIR table[2] = {
        {ADI_DCB_CMD_FLUSH_QUEUE, (void*)ClientCallback,
        {ADI_DCB_CMD_END, 0}
```

```
        );

        adi_dcb_Control(
                hServer,
                ADI_DCB_CMD_TABLE,
                (void*)table

        );
```

Refer to "ADI_DCB_COMMAND" on page 5-26 for the complete list of commands and associated values.

Prototype

```
ADI_DMA_RESULT adi_dcb_Control(
        ADI_DCB_HANDLE hServer,
        ADI_DCB_COMMAND command,
        void *value
);
```

Arguments

hServer	Handle of the required queue server to close.
command	ADI_DCB_COMMAND enumeration value specifying the meaning of the associated value argument. See "ADI_DCB_COMMAND" on page 5-26.
value	Required value, a single value, a command-value pair, or a table of command-value pairs

Return Value

In debug mode, this routine returns one of the following result codes; otherwise, ADI_DCB_RESULT_SUCCESS is always returned.

ADI_DCB_RESULT_NO_SUCH_QUEUE	Handle of the required queue server is invalid.
ADI_DCB_RESULT_BAD_COMMAND	Either the command kind or the value specified is invalid.

adi_dcb_Init

Description

The `adi_dcb_Init` function initializes the DCB manager with sufficient memory for the required number of deferred callback queues (referred to as *queue servers*).

This function can be called once per processor core.

Prototype

```
ADI_DCB_RESULT adi_dcb_Init(
        void            *ServerMemData,
        size_t          szServer,
        unsigned int    *NumServers
        void            *hCriticalRegionData
);
```

Arguments

`ServerMemData`	Pointer to an area of memory used to hold the data associated with each registered queue server
`szServer`	Length in bytes of memory supplied for the queue server data.
`NumServers`	On return, this argument holds the maximum number of simultaneously open queue servers that the supplied memory can support.
`hCriticalRegionData`	Handle to data area containing critical region data. This is passed to `adi_int_EnterCriticalRegion` where it is used internally by the module. See "Interrupt Manager" for further details.

Return Value

In debug mode, this routine returns one of the following result codes; otherwise, ADI_DCB_RESULT_SUCCESS is always returned.

ADI_DCB_RESULT_SUCCESS	Successfully initialized the queue server.
ADI_DCB_RESULT_NO_MEMORY	Insufficient memory for one queue entry was encountered.
ADI_DCB_RESULT_CALL_IGNORED	DCB manager has already been initialized for this processor core.

adi_dcb_Open

Description

The `adi_dcb_Open` function opens a queue server for use by assigning memory for its callback queue. Additionally, in standalone mode, the queue is assigned to the requested IVG priority level and the DCB manager's `adi_dcb_DispatchCallbacks` function is hooked to the interrupt handler chain with the interrupt manager for the given IVG level.

> The interrupt manager must be initialized prior to opening a queue server.

Prototype

```
ADI_DCB_RESULT adi_dcb_Open (
      u32               IvgLevel,
      void              *QueueMemData,
      size_t            szQueue,
      u32               *NumEntries,
      ADI_DCB_HANDLE    *hServer
);
```

Arguments

IvgLevel	IVG level at which the DCB manager's dispatcher function operates. This value is ignored in the VDK version of the library.
QueueMemData	Pointer to an area of memory used to hold the data associated with the server's entry queue
szQueue	Length in bytes of memory supplied for the queue
NumEntries	On return, this argument holds the maximum number of queue entries that the supplied memory can support.
hServer	On return, this argument contains a handle to the queue server opened. This is used to uniquely identify the queue server in calls to other API functions within the SSL.

Return Value

In debug mode, this routine returns one of the following result codes; otherwise, `ADI_DCB_RESULT_SUCCESS` is always returned.

ADI_DCB_RESULT_SUCCESS	Queue server was successfully initialized.
ADI_DCB_RESULT_NO_MEMORY	Insufficient memory for one queue entry was encountered.
ADI_DCB_RESULT_QUEUE_IN_USE	Queue server has already been opened for use by the specified IVG.

adi_dcb_Post

Description

The `adi_dcb_Post()` function posts a callback function and associated argument values to the queue server, identified by the handle argument for further processing.

A callback is associated with a priority level such that higher-priority callbacks run before lower-priority callbacks. To run all callbacks at the same priority level, assign the same priority to each callback posted.

Prototype

```
ADI_DCB_RESULT adi_dcb_Post(
      ADI_DCB_HANDLE        *hServer,
      u16                   Priority;
      ADI_DCB_CALLBACK_FN   Callback,
      void                  *pHandle,
      u32                   u32Arg,
      void                  *pArg
);
```

Arguments

Table 5-1. Adi_dcb_Post Arguments

Argument	Explanation
hServer	Handle of the required queue server
Priority	Priority level at which the callback runs; the lower the number, the higher the priority. There is no real limit on the value supplied.
Callback	Address of the client callback function queued
pHandle	void* address passed as the first argument to the callback function upon its deferred execution. Typically it is a handle address that is meaningful within the context of the callback function. For example, when used within the interrupt handler of the DMA manager, this argument is the ClientHandle value defined when the DMA channel was opened.
u32Arg	u32 value passed as the second argument to the callback function upon its deferred execution. (See "ADI_DCB_CALLBACK_FN" on page 5-25.) Typically, it is a value that is meaningful within the context of the callback function. For example, when used within the interrupt handler of the DMA manager, this argument describes the nature of the event that has occurred.
pArg	void* value passed as the third argument to the callback function upon its deferred execution. (See "ADI_DCB_CALLBACK_FN" on page 5-25.) Typically, it is an address of a block of data. For example, when called within the interrupt handler of the DMA manager, this argument points to the start of the buffer for which the DMA transfer has completed.

Return Value

In debug mode, this routine returns one of the following result codes. Otherwise, ADI_DCB_RESULT_SUCCESS is always returned.

ADI_DCB_RESULT_SUCCESS	Entry was successfully queued.
ADI_DCB_RESULT_NO_MEMORY	No vacant queue entry available.
ADI_DCB_RESULT_NO_SUCH_QUEUE	Handle provided does not represent a valid queue server.

adi_dcb_Remove

Description

The adi_dcb_Remove() function removes entries in the given queue that match the address of the given callback function. Alternatively, passing a NULL value for the callback function address instructs the callback manager to remove all entries in the queue.

Prototype

```
ADI_DCB_RESULT adi_dcb_Remove(
       ADI_DCB_HANDLE        hServer,
       ADI_DCB_CALLBACK_FN   Callback
);
```

Arguments

hServer	Handle of the required queue server
Callback	Address of the client callback function removed. If NULL, then all entries in the queue are removed, otherwise all entries matching the given callback function address are removed.

Return Value

In debug mode, this routine returns one of the following result codes; otherwise, ADI_DCB_RESULT_FLUSHED_OK is always returned.

ADI_DCB_RESULT_FLUSHED_OK	Entries were successfully removed.
ADI_DCB_RESULT_NONE_FLUSHED	Routine found no entries to be removed.
ADI_DCB_RESULT_NO_SUCH_QUEUE	Handle provided does not represent a valid queue server.

adi_dcb_Terminate

Description

The `adi_dcb_Terminate()` function terminates the DCB manager by dissociating the supplied memory (see "adi_dcb_Init" on page 5-17) and critical region data.

Prototype

```
ADI_DCB_RESULT
adi_dcb_Terminate ( void );
```

Return Value

`ADI_DCB_RESULT_SUCCESS` is always returned.

Public Data Types and Macros

This section provides descriptions of the public data types and macros.

ADI_DCB_CALLBACK_FN

The ADI_DCB_CALLBACK_FN data type defines the prototype for the callback functions to be posted:

```
typedef void (*ADI_DCB_CALLBACK_FN)
        (void* pHandle, u32 u32Arg, void* pArg);
```

where the values of the arguments are those passed to the adi_dcb_Post function when the callback is queued for deferred execution.

ADI_DCB_COMMAND_PAIR

The ADI_DCB_COMMAND_PAIR data type is used to enable the generation of a table of control commands to be sent to the DCB manager via the adi_dcb_Control function.

```
typedef struct ADI_DCB_COMMAND_PAIR {
        ADI_DCB_COMMAND kind;
        void *value;
} ADI_DCB_COMMAND_PAIR;
```

For valid values for the kind field, refer to "ADI_DCB_COMMAND" on page 5-26.

For example, the following command could be sent to the DCB manager to flush all callbacks in the queue:

```
ADI_DCB_COMMAND_PAIR CMD = { ADI_DCB_CMD_FLUSH_QUEUE, NULL };
```

ADI_DCB_COMMAND

The ADI_DCB_COMMAND is used to control the DCB manager's queue server. This data type is used in an ADI_DCB_COMMAND_PAIR couplet to change a configuration value in calls to adi_dcb_Control.

Command	Associated Data Value
ADI_DCB_CMD_END	Defines the end of a table of command pairs.
ADI_DCB_CMD_PAIR	Tells adi_dcb_Control that a single command pair is being passed.
ADI_DCB_CMD_TABLE	Tells adi_dcb_Control that a table of command pairs is being passed.
ADI_DCB_CMD_FLUSH_QUEUE	Address of the callback function for which all matching queue entries are cleared from the queue, regardless of priority.

ADI_DCB_ENTRY_HDR

The ADI_DCB_ENTRY_HDR structure is provided to interface with the underlying RTOS through the adi_dcb_Forward function (refer to "adi_dcb_Forward" on page 5-9):

```
typedef struct ADI_DCB_ENTRY_HDR (
   struct ADI_DCB_ENTRY *pNext;            // Next item in queue
   ADI_DCB_DEFERRED_FN pDeferredFunction; // Deferred Callback
                                          // Function pointer,
} ADI_DCB_ENTRY_HDR;
```

where pNext points to the next item in the queue and pDeferredFunction is the address of the deferred function, which is always the address of adi_dcb_DispatchCallbacks.

The ADI_DCB_DEFERRED_FN typedef defines the prototype for this function:

```
typedef void (*ADI_DCB_DEFERRED_FN) (ADI_DCB_ENTRY *);
```

ADI_DCB_RESULT

All public DCB manager functions return a result code of the ADI_DCB_RESULT data type. Possible values include the following.

ADI_DCB_RESULT_SUCCESS	Queue server was successfully initialized.
ADI_DCB_RESULT_NO_MEMORY	Insufficient memory for one queue entry was present.
ADI_DCB_RESULT_QUEUE_IN_USE	Queue server has already been opened for use by the specified IVG. See “ADI_DCB_COMMAND” on page 5-26.
ADI_DCB_RESULT_CALL_IGNORED	DCB manager has already been initialized for this processor core. See “ADI_DCB_COMMAND” on page 5-26.
ADI_DCB_RESULT_NO_SUCH_QUEUE	Handle provided does not represent a valid queue server registered with the DCB manager.
ADI_DCB_RESULT_BAD_COMMAND	Either the command kind or the value specified is invalid.

6 DMA MANAGER

This chapter describes features of the direct memory access (DMA) manager and its application programming interface (API).

This chapter contains:

Introduction

The DMA manager provides the application developer with the means to manage DMA traffic on as many channels as required across the spectrum—from setting up the DMA channels for their intended purpose, to providing callbacks to the client application on transfer completion.

As part of the system services, the DMA manager provides a complete and easy-to-use interface to the DMA controller. To this end, the DMA manager is designed to:

- Remove the need for direct client access to memory-mapped registers (MMRs) through the implementation of application programming interface (API) function calls.
- Place no limitations on the type of data transfer. All descriptor types are supported as well as single and circular buffers. Both one-dimensional (1-D) and two-dimensional (2-D) DMA can be used.
- Provide a simple interface to perform block copies of data between different memory locations using both 1-D and 2-D memory DMA, such that blocks of data can be copied between internal and external memory with one function call in an equivalent manner to the C library `memcpy` function.
- Interpret interrupts raised on DMA transfer completion and pass higher-level event information to user-supplied callback functions. For example, if an interrupt is raised on each inner loop of a circular 2-D DMA transfer, an event can be passed to the callback function at the completion of each inner loop.

- Minimize the memory used by the module. No static memory space is set aside within the API framework to hold the configuration details for each channel. Instead, a mechanism is provided to enable client applications to set aside sufficient memory for as many DMA channels as application requires.
- Be as portable as possible by providing a consistent interface across all processor families and variants. Additionally, the DMA manager uses an unambiguous naming convention to safeguard against conflicts with other software libraries provided by Analog Devices or elsewhere.

  To this end, all enumeration values and `typedef` statements use the `ADI_DMA_` prefix, and functions and global variables use the lowercase `adi_dma_` equivalent.

Theory of Operation

This section describes the internal operation of the DMA manager.

Overview

The DMA manager is used to control the Blackfin processor's DMA controller. The DMA manager supports peripheral DMA to move data to and from the various on-board peripherals and uses memory DMA to move data between the various memory spaces of the Blackfin processor.

The DMA manager is capable of controlling any number of DMA channels. You specify which channels the DMA manager controls. The application can use the remaining channels (those channels not under control of the DMA manager) for any purpose; that is, the channels are controlled independently of the DMA manager.

Various data transfer modes of the Blackfin processor's DMA controller are supported, including descriptor chains, circular buffers (utilizing the autobuffer capability of the Blackfin processor), and one-shot transfers. One-dimensional (linear) transfers and two-dimensional (matrix) transfers are supported.

The DMA manager can be directed to notify the client (through the client's callback function) when data transfers complete. Additionally, the client's callback function is invoked when an unexpected event, such as a DMA error, occur. As with all system services, the DMA manager allows the client to specify callbacks to be "live", meaning the client's callback function is invoked at hardware interrupt time, or "deferred", meaning the client's callback function is invoked outside the context of the hardware interrupt.

DMA Manager Initialization

In order to use the DMA manager, the client must first initialize it. The DMA manager does not use static data, so the initialization step is used to give the DMA manager memory for use in managing the DMA controller.

The DMA manager requires a small, fixed amount of base memory and a variable amount of memory, depending the number of simultaneously open DMA channels the system requires. Note that memory DMA requires two DMA channels—one channel for the source and another channel for the destination for each memory DMA stream. Macros are provided to define the amount of memory (in bytes) required for the base and channel memory. These macros are `ADI_DMA_BASE_MEMORY` and `ADI_DMA_CHANNEL_MEMORY`.

For example, if the client wants to initialize the DMA manager and has at most four DMA channels and one memory DMA stream open simultaneously, the amount of required memory is:

```
(ADI_DMA_BASE_MEMORY + (ADI_DMA_CHANNEL_MEMORY * 6)).
```

When called, the initialization function, adi_dma_Init(), initializes the memory that was passed in. Like all functions within the DMA manager, the initialization function returns a return code that indicates success or the specific error that occurred during the function call. All DMA API functions return the ADI_DMA_RESULT_SUCCESS value to indicate success. All error codes are of the form ADI_DMA_RESULT_XXXX.

In addition to the return code, the adi_dma_Init() function returns a count of the number of channels it can manage simultaneously and a handle to the DMA manager. The channel count can be tested to ensure that the DMA manager can control the requested number of channels. The DMA manager handle value that is returned is later passed into the adi_dma_Open and adi_dma_MemoryOpen functions which use the manager handle to identify the DMA manager that is to control the channel. Passing in this handle allows these functions to quickly identify the memory that is used to manage the open channel(s). After the DMA manager is initialized, DMA channels and memory streams can be opened for use.

Although it is possible to create multiple DMA managers in a single-core Blackfin system, there is no practical advantage in doing so.

DMA Manager Termination

When the DMA manager is no longer needed, the client can terminate the DMA manager with the adi_dma_Terminate function. This function is passed the DMA manager handle given to the client in the adi_dma_Init function. The DMA manager closes any open channels and streams and then returns to the caller. After the return from the adi_dma_Terminate() function, the memory that was supplied to the DMA manager via the adi_dma_Init() function can be reused by the client.

In many embedded systems, the DMA manager is never terminated.

Memory DMA and Peripheral DMA

As described in the Blackfin processor's *Hardware Reference*, the Blackfin processor's DMA controller supports both peripheral DMA and memory DMA. Regardless of whether peripheral DMA or memory DMA is being used, the client schedules DMA manager activity on a block-by-block basis, rather than a sample-by-sample basis. Though a block of data can be defined to be a single sample of data, this is seldom the case. Most often, data is blocked in quantities relevant to the processing to be performed. The term *buffer* is used throughout this document to represent the block of data.

Peripheral DMA moves blocks of data between on-chip peripherals and one of the memory spaces of the Blackfin processor (most commonly within the context of a device driver). For example, an on-chip peripheral such as a PPI uses DMA to move blocks of data into (or out of) the PPI device. As such, the device driver for the PPI typically uses the DMA manager to control dataflow through the PPI.

Memory DMA describes the movement of data between any of the various Blackfin processor's memory spaces. For example, due to the large amounts of data used for video processing, video frames may be stored in external SDRAM and then "DMA-ed" piecemeal into internal L1 memory for processing.

The DMA manager fully supports peripheral DMA and memory DMA. When using peripheral DMA, clients leverage the capabilities of the DMA manager on a channel-by-channel basis. When using memory DMA, clients can choose to control memory streams as individual source and destination channels using the same techniques and functions provided for peripheral DMA, or alternatively can control memory DMA as a single memory stream using the higher-level `adi_dma_MemoryXXXX()` functions.

Controlling Memory Streams

When memory DMA is needed, controlling and scheduling memory DMA is accomplished most easily using higher level memory streams. The `adi_dma_MemoryXXXX()` functions provide a simple, efficient method of transferring data between the various memory spaces by the Blackfin processor's DMA controller.

The overall sequence for using memory streams is to open the memory stream, schedule transfers as needed, and then close the memory stream when it is no longer needed. In many embedded systems, the memory stream is never closed, but remains open at all times.

Opening Memory Streams

To open the memory stream, the client calls the `adi_dma_MemoryOpen` function. The client passes the following parameters into the function:

- A handle to the DMA manager that controls the stream
- The stream ID (of type `ADI_DMA_STREAM_ID`) that identifies the memory DMA stream to use
- A client handle that is passed back to the client's callback function. This is a client-supplied value, supposedly of some meaning to the client, which is passed back to the client's callback function so that the client can associate this value with the stream that is causing the callback.
- A pointer to a location into which the DMA manager stores the stream handle. The stream handle is a DMA manager-defined value that uniquely identifies the stream to the DMA manager.
- A handle to a deferred callback service (typically from the deferred callback service) or a NULL value. If a NULL value is supplied, the DMA manager makes *live* callbacks to the application. Live callbacks are made during hardware interrupt time. If a deferred

callback service handle is provided, all callbacks for the stream use the deferred callback service to defer callback processing until after hardware interrupt time.

Memory Transfers

Once a memory stream has been opened, the client can submit jobs to the stream using the `adi_dma_MemoryCopy` and/or `adi_dma_MemoryCopy2D` functions. Linear (one-dimensional) memory transfers use the former function; two-dimensional transfers use the latter function. The same stream can be used for one-dimensional and two-dimensional transfers, so a client can schedule a one-dimensional transfer on a given stream, and can then schedule a two-dimensional transfer on that same stream.

Note that a memory stream supports only one transfer at a time. If one transfer is in progress and another transfer is requested, these functions return an error code indicating the stream is in use. If queuing of memory transfers is required, this can be accomplished by using the channel-based method of controlling DMA.

One-Dimensional Transfers (Linear Transfers)

One-dimensional (linear) transfers are handled by calling the `adi_dma_MemoryCopy()` function. When calling the `adi_dma_MemoryCopy()` function, the client provides the following parameters:

- The stream handle. This is the value provided to the client during the `adi_dma_MemoryOpen()` function.
- The destination starting address into whichdata is copied
- The source starting address from which data is copied
- The width of each element (in bytes) to be copied. The DMA manager uses this value to schedule 8-, 16-, or 32-bit transfers.

- A count of the number of elements copied
- The address of the callback function to be called when the transfer is complete. The invocation of the callback function depends on the callback service handle value that was supplied to the stream when it was opened, either deferred or live.

  If the `adi_dma_MemoryCopy()` function is passed a NULL value for the callback function address, the transfer occurs synchronously and the `adi_dma_MemoryCopy()` function does not return to the client until the transfer is complete. No callbacks are made in this case.

Two-Dimensional Transfers

Two-dimensional (matrix) memory transfers are handled by calling the `adi_dma_MemoryCopy2D()` function. When calling this function, the client provides the following parameters:

- The stream handle. This is the value provided to the client during the `adi_dma_MemoryOpen()` function.
- A pointer to a data structure (of type `ADI_DMA_2D_TRANSFER`) that defines how data is stored into the destination memory
- A pointer to a data structure (of type `ADI_DMA_2D_TRANSFER`) that defines how data is read from the source memory
- The width of each element (in bytes) copied. The DMA manager uses this value to schedule 8-, 16-, or 32-bit transfers.

- The address of the callback function that is called when the transfer is complete. The invocation of the callback function depends on the callback service handle value supplied to the stream when it was opened (either deferred or live).

  If the `adi_dma_MemoryCopy()` function is passed a NULL value for the callback function address, the transfer occurs synchronously and the `adi_dma_MemoryCopy()` function does not return to the client until the transfer is complete. No callbacks are made in this case.

The `ADI_DMA_2D_TRANSFER` data type structure holds the necessary values to specify a two-dimensional transfer. This data type contains the starting address in memory, an `XCount` value that defines the number of columns, a `YCount` value that defines the number of rows, and `XModify` and `YModify` values to describe the stride for each.

Closing Memory Streams

When a memory stream is no longer needed, the `adi_dma_MemoryClose` function is called to close the stream. Once closed, a stream must be reopened before it can perform additional transfers. The client passes the following parameters into the function:

- The stream handle. This is the value provided to the client during the `adi_dma_MemoryOpen` function.
- A flag to indicate whether the DMA manager should wait for the completion of any ongoing transfers on the stream before closing the channel

Controlling DMA Channels

Controlling DMA on a channel-by-channel basis allows for the tightest control of DMA scheduling. Before a channel can be used, it must be opened first and then configured.

Opening DMA Channels

To open a DMA channel, the client calls the `adi_dma_Open()` function. The client passes into the function the following parameters:

- A handle to the DMA manager that controls the channel
- The channel ID (of type `ADI_DMA_CHANNEL_ID`) that identifies the DMA channel to open
- A client handle that is passed back to the client's callback function. This is a client-supplied value, providing some meaning to the client, which is passed back to the client's callback function so the client can associate this value with the stream causing the callback.
- A pointer to a location into which the DMA manager stores the channel handle. The channel handle is a DMA manager-defined value that uniquely identifies the channel to the DMA manager.
- The operating mode that defines how the channel moves data. Refer to the sections starting with "Single Transfers" on page 6-12.
- A handle to a deferred callback service (typically from the deferred callback service) or a NULL value. If a NULL value is supplied, the DMA manager makes live callbacks to the application. Live callbacks are made during hardware interrupt time. If a deferred callback service handle is provided, all callbacks for the stream use the deferred callback service to make callbacks occur at non-hardware interrupt time.
- The address of the callback function that is called to notify the client of events. Events may be expected events (such as requests for notification when a transfer is complete) to unexpected events (such as a DMA error). When the callback function is actually invoked, deferred or live, depends on the callback service handle value that is supplied.

After the channel has been successfully opened, the channel can be configured, buffers can be supplied to the channel, and so on. Note that the actual transfer of data does not begin with the adi_dma_MemoryOpen function. Dataflow must be enabled specifically via the adi_dma_Control function.

The DMA manager supports the following operational modes of the Blackfin processor's DMA controller:

- "Single Transfers"
- "Circular Transfers" on page 6-14
- "Large Descriptor Chaining Model" on page 6-16
- "Small Descriptor Chaining Model" on page 6-20

Single Transfers

The single transfer operating mode (ADI_DMA_MODE_SINGLE) transfers individual, single buffers of data. When using the single transfer mode, the client calls the adi_dma_Buffer() function to schedule a transfer. The client passes the following parameters to the function:

- The channel handle. This is the value provided to the client during the adi_dma_Open() function.
- The starting address of the buffer. This value is the address in memory where data is initially read (for outbound data) or the address in memory where data is initially stored (when the transfer is for inbound data).
- The configuration word for the transfer. This is a 16-bit value that represents the DMA configuration control register for the channel. The DMA manager include file provides macros, that allow the client to quickly and easily create a configuration word. The following fields within the configuration word are the only fields for which values must be provided.

`WNR` (Transfer Direction)	`ADI_DMA_WNR_READ`	Transfer is for outbound data.
	`ADI_DMA_WNR_WRITE`	Transfer is for inbound data.
`WDSIZE` (Transfer Element Size)	`ADI_DMA_WD_SIZE_8BIT`	Elements are 1 byte wide (8 bits).
	`ADI_DMA_WD_SIZE_16BIT`	Elements are 2 bytes wide (16 bits).
	`ADI_DMA_WD_SIZE_32BIT`	Elements are 4 bytes wide (32 bits).
`DMA2D` (Dimension Select)	`ADI_DMA_DMA2D_LINEAR`	One-dimensional (linear) transfer
	`ADI_DMA_DMA2D_2D`	Two-dimensional transfer
`DI_SEL` (Data Interrupt Timing Select) Applies only when DMA2D = 1	`ADI_DMA_DI_SEL_OUTER_LOOP`	A callback is generated when the entire transfer has completed (outer loop).
	`ADI_DMA_DI_SEL_INNER_LOOP`	A callback is generated on each inner loop completion.
`DI_EN` (Data Interrupt Enable)	`ADI_DMA_DI_EN_DISABLE`	No callback is generated.
	`ADI_DMA_DI_EN_ENABLE`	The DMA manager generates a callback to the client when the transfer completes.

- The `XCount` value. For one-dimensional transfers, this value defines the number of elements to transfer. For two-dimensional transfers, this value defines the inner loop count (number of columns).
- The `XModify` value. For one-dimensional transfers, this value defines the address increment/decrement (stride) for each successive element. For two-dimensional transfers, this value defines the inner loop address increment/decrement (stride) for each successive element up to but not including the last element in each inner loop. After the last element in each inner loop, the `YModify` value is applied instead, except on the very last element of the transfer.

- The YCount value. This parameter is ignored for one-dimensional transfers. For two-dimensional transfers, the value represents the outer loop count (number of rows).
- The YModify value. This parameter is ignored for one-dimensional transfers. For two-dimensional transfers, this value defines the outer loop address increment/decrement (stride) that is applied after each inner loop completion. This value is the offset between the last element of one row and the first element of the next row.

Regardless of whether dataflow on the channel is enabled, the adi_dma_Buffer() function returns immediately to the caller. If dataflow is already enabled on the channel, the DMA manager begins executing the transfer; otherwise, the transfer does not begin until the dataflow is enabled via the adi_dma_Control() function. When using the single-transfer mode, the adi_dma_Buffer() function can be called at any time, as long as a transfer on the channel is not already in progress.

Circular Transfers

The circular transfer mode (ADI_DMA_MODE_CIRCULAR) leverages the auto-buffer capability of the DMA controller. Using the circular transfer mode, the client provides the DMA manager with a single contiguous buffer comprising *n* sub-buffers, as shown in Figure 6-1 on page 6-16.

When dataflow is enabled, the DMA manager begins transferring data at the start of the buffer, continuing on throughout the entire buffer, and then automatically looping back to the top of the buffer again, repeating indefinitely. Optionally, the client can direct the DMA manager to generate callbacks at the completion of each sub-buffer, to generate callbacks at the completion of the entire buffer, or not to generate callbacks.

When using circular transfer mode, the client calls the adi_dma_Buffer() function with the following parameters:

- The channel handle. This is the value provided to the client during the adi_dma_Open() function.
- The starting address of the buffer. This value is the address in memory where data is initially read from (when the transfer is for outbound data), or the address in memory where data is initially stored (when the transfer is for inbound data).
- The configuration word for the transfer. This 16-bit value represents the DMA configuration register for the channel. The DMA manager include file provides macros that allow the client to quickly and easily create a configuration word. The client provides values for the following fields within the configuration word.

WNR (Transfer Direction)	ADI_DMA_WNR_READ	A transfer is for outbound data.
	ADI_DMA_WNR_WRITE	A transfer is for inbound data.
DI_SEL (Data Interrupt Timing Select)	ADI_DMA_DI_SEL_OUTER_LOOP	A callback is generated on completion of whole buffer only.
	ADI_DMA_DI_SEL_INNER_LOOP	A callback is generated on each inner loop completion.
DI_EN (Data Interrupt Enable)	ADI_DMA_DI_EN_DISABLE	No callback will be generated.
	ADI_DMA_DI_EN_ENABLE	Callbacks are generated according the setting of DI_SEL.

- The XCount value. Set this parameter to the number of elements in a single sub-buffer.
- The XModify value. The width (in bytes) of an element. Allowed values are 1, 2, and 4 only.

- The YCount value. Set this parameter to the number of sub-buffers contained within the whole buffer.
- The YModify value. This parameter is ignored.

When using the circular mode, the adi_dma_Buffer() function must be called prior to enabling dataflow on the channel. After enabling dataflow, if the client wants to change to a different circular buffer, the client must first disable dataflow on the channel, call the adi_dma_Buffer() function with the new buffer data, and then re-enable dataflow on the appropriate channel.

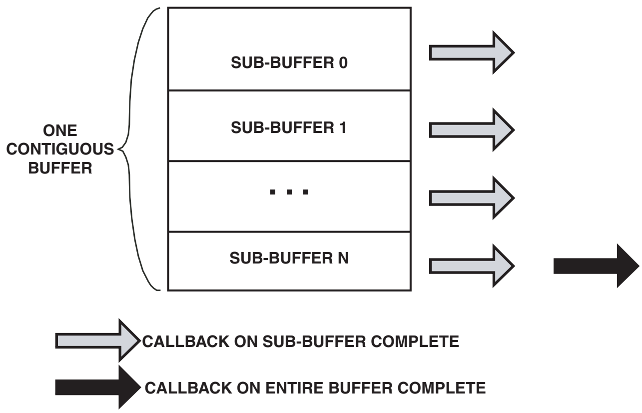


Figure 6-1. Circular Buffer Usage in a Circular Transfer

Large Descriptor Chaining Model

The large descriptor chaining model (ADI_DMA_MODE_DESCRIPTOR_LARGE) allows the client to create chains of descriptors, residing anywhere in memory, where each descriptor describes a specific work unit.

Using the large descriptor chaining mode, the client provides the DMA manager with one or more descriptor chains, as shown in Figure 6-2.

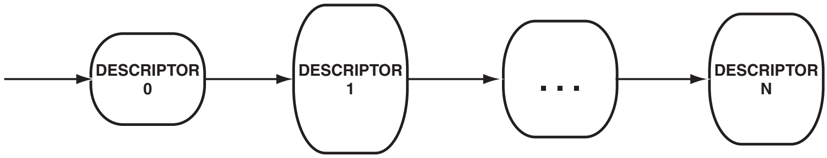


Figure 6-2. Descriptor Chain

Descriptors can be submitted at any time, regardless of the dataflow state. The DMA manager maintains independent queues of descriptors for each channel, keeping the DMA controller busy with transfers until all queued descriptors are processed.

Both one-dimensional and two-dimensional transfers can be intermixed on the same channel. Each transfer can define a different transfer type, length, and so on. Additionally, callbacks to the client's callback function can be made upon completion of every descriptor, any individual descriptor, or configured to never call back.

When the large descriptor chaining mode is used, descriptor chains are submitted to the channel using the `adi_dma_Queue()` function with the following parameters:

- The channel handle. This is the value provided to the client during the `adi_dma_Open()` function.
- A handle of the type `ADI_DMA_DESCRIPTOR_HANDLE` to a descriptor. Because the same `adi_dma_Queue()` function is used for all descriptor-based operating modes (including large descriptors, small descriptors, and arrays of descriptors), the `ADI_DMA_DESCRIPTOR_HANDLE` data type acts as a container that conveniently represents each of the descriptor types.

For the large descriptor chaining mode, descriptors are of the type `ADI_DMA_DESCRIPTOR_LARGE`, which is a data type that defines a large model descriptor. When calling the `adi_dma_Queue()` function, the client can pass in the address of the descriptor union (ADI_DMA_DESCRIPTOR_UNION) or alternatively, the address of the descriptor itself (ADI_DMA_DESCRIPTOR_LARGE) to the ADI_DMA_DESCRIPTOR_HANDLE data type. This descriptor can be a single descriptor or the first descriptor in a chain of descriptors.

Large model descriptors contain all the information necessary for the DMA manager to control the operation of the DMA controller. This information includes:

- A pointer to the next large descriptor in the chain. If this field is NULL, the given descriptor is the only descriptor the client is submitting to the channel.
- The starting address of the buffer. This value is the address in memory where data is initially read from (when the transfer is for outbound data), or the address in memory where data is initially stored (when the transfer is for inbound data).
- The configuration word for the transfer. This 16-bit value represents the DMA configuration register for the channel. The DMA manager include file provides macros that allow the client to quickly and easily create a configuration word. The client provides the following values to fields within the configuration word.

WNR (Transfer Direction)	ADI_DMA_WNR_READ	Transfer is for outbound data.
	ADI_DMA_WNR_WRITE	Transfer is for inbound data.
WDSIZE (Transfer Element Size)	ADI_DMA_WD_SIZE_8BIT	Elements are 1 byte wide (8 bits).
	ADI_DMA_WD_SIZE_16BIT	Elements are 2 bytes wide (16 bits).
	ADI_DMA_WD_SIZE_32BIT	Elements are 4 bytes wide (32 bits).
DMA2D (Dimension Select)	ADI_DMA_DMA2D_LINEAR	One-dimensional (linear) transfer
	ADI_DMA_DMA2D_2D	Two-dimensional transfer

DI_EN (Data Interrupt Enable)	ADI_DMA_DI_EN_DISABLE	No callback is generated.
	ADI_DMA_DI_EN_ENABLE	The DMA manager generates a callback to the client when the transfer completes.

- The XCount value. For one-dimensional transfers, this value defines the number of elements to be transferred. For two-dimensional transfers, this value defines the inner loop count (number of columns).
- The XModify value. For one-dimensional transfers, this value defines the address increment/decrement (stride) for each successive element. For two-dimensional transfers, this value defines the inner loop address increment/decrement (stride) for each successive element up to but not including the last element in each inner loop. After the last element in each inner loop, the YModify value is applied instead, except on the very last element of the transfer.
- The YCount value. This parameter is ignored for one-dimensional transfers. For two-dimensional transfers, the value represents the outer loop count (number of rows).
- The YModify value. This parameter is ignored for one-dimensional transfers. For two-dimensional transfers, this value defines the outer loop address increment/decrement (stride) that is applied after each inner loop completion. This value is the offset between the last element of one row and the first element of the next row.

The DMA manager does not constrain when descriptors can be provided to a channel. For DMA channels that process inbound data, it is best practice to provide descriptors to the channel via the adi_dma_Queue() function before enabling dataflow. By doing this, the DMA controller uses a space where data can be stored. If dataflow is enabled on an inbound channel prior to providing descriptors, it is possible for data to be received by the DMA channel but not have anywhere to store it.

Small Descriptor Chaining Model

The small descriptor chaining model (ADI_DMA_MODE_DESCRIPTOR_SMALL) is similar to the large descriptor chaining model. The only material difference between the two models is that in the small descriptor model, the pointer to the next descriptor in a chain of descriptors consists of only the lower 16 bits of address, rather than a full 32-bit address. This means that all descriptors on a channel that use the small descriptor model must have the same upper 16 bits of address. In other words, all small model descriptors for a channel must be located within the same 64KB segment.

This difference is encapsulated in the ADI_DMA_DESCRIPTOR_SMALL data type. In order to avoid data alignment issues, a consequence of having the next descriptor pointer exist as a 16-bit entry rather than a 32-bit entry, the starting address of the data within the descriptor is declared as two 16-bit entries, rather than a single 32-bit entry. Performing two 16-bit accesses, rather than a single 32-bit access, avoids alignment exceptions.

Other than these differences, the small descriptor chaining model is functionally identical to the large descriptor chaining model.

Arrays of Descriptors

The descriptor array mode (ADI_DMA_MODE_DESCRIPTOR_ARRAY) is not yet supported in the device manager.

Configuring a DMA Channel

Once a DMA channel has been opened, the client can detect and modify the configuration of the channel via the adi_dma_Control function. The complete list of configuration control commands are provided in Table 6-3 on page 6-62. In most cases, the client passes the following parameters to the adi_dma_Control() function:

- The channel handle. This is the value provided to the client during the adi_dma_Open function.

- The command ID. This `ADI_DMA_CMD` data type identifies the controllable item that is configured.
- A command-specific value. The semantics of this parameter are defined by the command ID. For example, given a command ID of `ADI_DMA_CMD_SET_DATAFLOW`, the command-specific value is either `TRUE` or `FALSE`, to enable or disable dataflow on the channel. The command-specific value is always cast to (`void*`).

Closing a DMA Channel

To close a DMA channel, the client calls the `adi_dma_Close()` function. The client passes the following parameters into the function:

- The channel handle. This is the value provided to the client during the `adi_dma_Open()` function.
- A flag indicating whether the DMA manager should wait for any DMA activity on the channel to complete before closing the channel.

Once a channel has been closed, the channel must be reopened with the `adi_dma_Open()` function before it can be used again.

Transfer Completions

Client applications can use two different mechanisms to determine when transfers complete. One method is by polling the channel, and the other method is through callbacks.

In addition to polling and callbacks, the memory stream functions offer a synchronous capability. When used synchronously, the `adi_dma_MemoryCopy()` and `adi_dma_MemoryCopy2D()` functions return to the client only when the transfer is complete.

Polling

Clients can use the adi_dma_Control() function to interrogate a specific channel to determine whether a transfer is in progress by using the ADI_DMA_CMD_GET_TRANSFER_STATUS command.

When given this command, the DMA manager examines the status of the individual DMA channel. The function provides a response of TRUE, if a transfer is in progress, and a response of FALSE, if no transfer is currently in progress.

Note that memory streams can also be interrogated for transfer status. Instead of passing the channel handle (ADI_DMA_CHANNEL_HANDLE) parameter to the adi_dma_Control() function, the client passes the stream handle (ADI_DMA_STREAM_HANDLE) parameter (casted to the ADI_DMA_CHANNEL_HANDLE data type) to the adi_dma_Control() function.

Callbacks

Callbacks are the more commonly used mechanism that clients use to determine when a transfer has completed. Callbacks are either live (meaning they are made at interrupt time) or deferred (meaning they are made after the hardware interrupt has completed processing using a callback service).

Memory Stream Callbacks

When using memory streams, if the client provided a callback function as a parameter to the adi_dma_MemoryCopy() or adi_dma_MemoryCopy2D() functions, the callback function is invoked by the DMA manager when the transfer is complete.

When using memory streams, the following arguments are passed to client callback functions:

- The client handle. This is the client-supplied value provided in the `adi_dma_MemoryOpen()` function.
- Event ID. This value is `ADI_DMA_EVENT_DESCRIPTOR_PROCESSED`.
- Starting destination address of the transfer

Circular Transfer Callbacks

When using the circular transfer method (`ADI_DMA_MODE_CIRCULAR`), the client uses the configuration word to specify the frequency of callbacks. When directed to callback the client on each sub-buffer completion, the DMA manager invokes the client's callback function after each sub-buffer completes. This is useful in double-buffering schemes, where two sub-buffers (ping/pong) are used.

When using circular transfers, the following arguments are passed to client callback functions:

- The client handle. This is the client-supplied value provided in the `adi_dma_Open()` function.
- Event ID. This value is `ADI_DMA_EVENT_INNER_LOOP_PROCESSED` when a sub-buffer has completed processing or `ADI_DMA_EVENT_OUTER_LOOP_PROCESSED` when the entire buffer has completed processing.
- Starting address of the data buffer

Descriptor Callbacks

When using any of the descriptor-based transfer methods (`ADI_DMA_MODE_DESCRIPTOR_LARGE`, `ADI_DMA_MODE_DESCRIPTOR_SMALL`, or `ADI_DMA_DESCRIPTOR_ARRAY`), the client uses the configuration word of the descriptor to define whether a callback is generated following processing of a descriptor. When directed to callback the client upon completion of the descriptor, the client callback function is passed the following arguments:

- The client handle. This is the client-supplied value provided in the `adi_dma_Open()` function.
- Event ID. This value is `ADI_DMA_EVENT_DESCRIPTOR_PROCESSED`.
- Starting address of the data

Descriptor-Based Sub-Modes

When using the small or large model descriptor-based transfers, two sub-modes (loopback and streaming) allow the client application greater flexibility in processing descriptors. Each of these sub-modes can be used independently or in combination. Each sub-mode is enabled or disabled via the `adi_dma_Control()` function. Clients that want to use these sub-modes must enable them prior to enabling dataflow on the channel. By default, both sub-modes are disabled.

Loopback Sub-Mode

The loopback sub-mode is controlled by the `ADI_DMA_CMD_SET_LOOPBACK` command.

When loopback sub-mode is enabled (after the DMA manager has processed the last descriptor in the chain of descriptors provided to a channel), it automatically loops back to the first descriptor provided to the channel. This effectively creates an infinite loop of descriptors as illustrated in Figure 6-3. For example, with loopback sub-mode, the client can provide the descriptors at initialization time, allow the DMA manager to process the descriptors, and never need to resupply the DMA manager with additional descriptors.

As in the non-loopback case, each descriptor, any one, none, or all descriptors can be tagged to generate a callback to the client after processing.

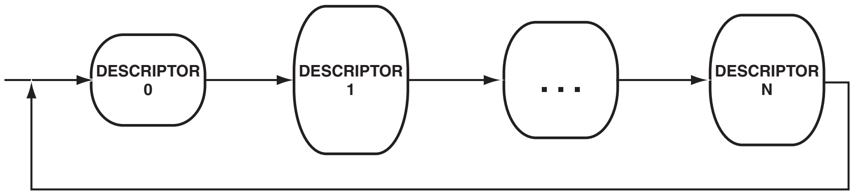


Figure 6-3. Descriptor Chain With Loopback

Streaming Sub-Mode

The streaming sub-mode is controlled by the `ADI_DMA_CMD_SET_STREAMING` command.

When not using streaming sub-mode, the DMA manager pauses the DMA controller after processing a descriptor that has been tagged to generate a callback has been processed. The DMA manager does this because the Blackfin processor's DMA controller does not provide any status information indicating that a specific descriptor has been processed. If the DMA manager did not pause the controller, it is possible that before the DMA manager can recognize and process the callback interrupt for a given descriptor, the DMA controller may have completed processing of yet another descriptor. Unless the DMA controller pauses until the DMA manager processes the interrupt, the DMA manager cannot definitively determine which callback interrupt is associated with which descriptor.

When not streaming, the DMA manager also pauses the DMA controller when a channel has exhausted its supply of descriptors.

The streaming sub-mode allows the client to alter this behavior. When the streaming sub-mode is enabled, the DMA manager never pauses the DMA controller; this allows the DMA transfers to occur at the maximum throughput rate.

When streaming, the client is required to ensure the following conditions:

- The channel always has descriptors to process and never runs out of descriptors.
- The system timing is such that the DMA manager can service the callback interrupt for any descriptor tagged for a callback, before another descriptor on the same channel that is tagged for callback is processed.

These conditions can be met fairly easily in most systems.

DMA Channel to Peripheral Mapping

The Blackfin processor allows the user to change the default mapping of the various DMA-supported peripherals to the various DMA channels. Typically, however, the mappings for the memory DMA channels are fixed and cannot be changed.

The DMA manager provides two functions, `adi_dma_GetMapping()` and `adi_dma_SetMapping()`, that allow the client to easily detect and change the mapping of DMA channels to peripherals. These functions can be called at any time after the DMA manager is initialized, but they must be processed before the channel is opened.

Sensing a Mapping

The client calls the adi_dma_GetMapping() function to detect the DMA channel ID to which a peripheral is mapped. The adi_dma_GetMapping() function takes the following parameters:

- The peripheral ID. This value, an ADI_DMA_PMAP type, enumerates the peripheral whose mapping is detected.
- Pointer to an ADI_DMA_CHANNEL_ID value. This value is the address of a location in memory into which the function stores the channel ID to which the given peripheral is mapped.

Setting a Mapping

The client calls the adi_dma_SetMapping() function to set the mapping of a given channel ID to a given peripheral. The client should take care to ensure that a one-to-one mapping exists between peripherals and channel IDs. The adi_dma_SetMapping() function takes the following parameters:

- The peripheral ID. This value, an ADI_DMA_PMAP type, enumerates the peripheral whose mapping is set.
- The channel ID. This value, an ADI_DMA_CHANNEL_ID value, enumerates the DMA channel to which the given peripheral is mapped.

Interrupts

The DMA manager uses the services of the interrupt manager to configure all DMA-related interrupts. All hooking of interrupts is isolated into the adi_dma_Open() and adi_dma_MemoryOpen() functions, and all unhooking of interrupts occurs in the adi_dma_Close() and adi_dma_MemoryClose() functions.

By default, the DMA manager uses the interrupt vector group (IVG) settings as set up by the interrupt manager. The client can alter the mapping of DMA channels to IVG levels via calls into the interrupt manager. See "Interrupt Manager" on page 2-1 for more information on altering mapping of DMA channels to IVGs.

Hooking Interrupts

When the client opens the first DMA channel, the `adi_dma_Open()` function hooks into the appropriate IVG chain for the DMA error interrupt. The handler for DMA errors does nothing other than clear the appropriate DMA error and notify the client's callback function that a DMA error occurred.

In addition to the DMA error interrupt, the `adi_dma_Open()` function hooks the DMA data interrupt handler into the appropriate IVG level for the given channel. The data interrupt handler is used to post callbacks resulting from the completion of DMA transfers. In addition to posting the notification callbacks, the data handler ensures that the channel is refreshed and restarted (if necessary) with any new pending transfers.

Unhooking Interrupts

When the last remaining open DMA channel is closed, the `adi_dma_Close()` function unhooks the DMA error handler from the appropriate IVG handler chain. In addition, if no other open channels are mapped to the same IVG as the channel being closed, the `adi_dma_Close()` function unhooks the DMA data handler from the chain of handlers for that IVG.

Two-Dimensional DMA

When using linear DMA, data is moved in a one-dimensional (linear) fashion. This is the most common type of transfer, where *n* elements of "W" width are moved from one location, or taken in through a device to another memory location, or out through a device.

Two-dimensional DMA is a convenient feature that allows data to be transferred in a non-linear fashion. This is especially useful in video applications. Two-dimensional DMA supports arbitrary row (`YCount`) and column (`XCount`) sizes up to 64K x 64K elements, as well as row modify values (`YModify`) and column modify values up to +/- 32K bytes.

When using channel DMA, descriptors are used to define the parameters for the transfer. When using memory streams, the `ADI_DMA_2D_TRANSFER` data type is used to define the parameters for the transfer.

For example, suppose you want to retrieve a 16 x 8 block of bytes (`data`) from a video frame buffer (`frame`) of size N x M pixels at location `frame[6][6]` and store it in a separate memory area (data) for processing. After the data has been processed, the values are then copied back to the original location.

Figure 6-4 illustrates the area of the frame to process.

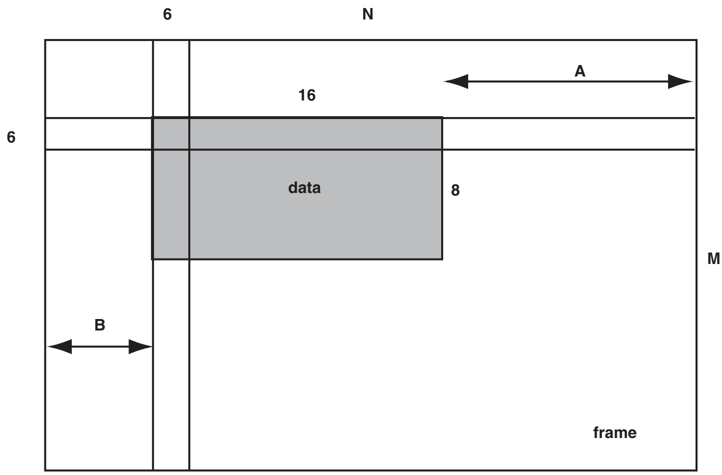


Figure 6-4. Selecting a 16 x 8 Block of Data From a Video Frame of Size N x M

To select each row of the 16 x 8 block, the inner loop of the required 2-D DMA configuration has 16 values (`XCOUNT=16`) and a stride (`XMODIFY`) of 1. The outer loop comprises 8 values (`YCOUNT=8`) and a stride (`YMODIFY`) of N-15 (A + B in Figure 6-4) chosen to instruct the DMA controller to jump from the end of one row to the start of the next.

It is also possible to extract interleaved data (for example, RGB values for a video frame) by modifying both the x and y `modify` values. For example, to receive a stream of R,G,B,R,G,B,… values from an N x M frame, consider Figure 6-5.

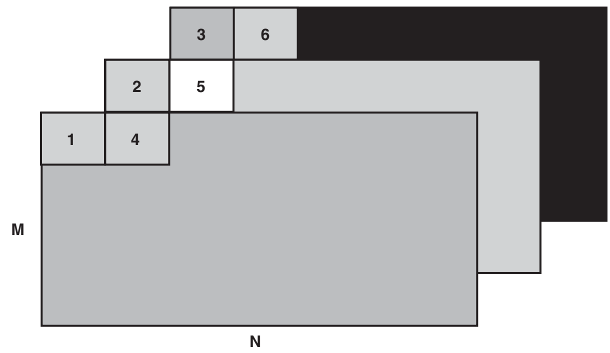


Figure 6-5. Capturing a Video Data Stream of (R,G,B Pixels) x (N x M Image Size)

In this case, the inner loop of the required 2-D DMA configuration has three values (`XCOUNT=3`) and a stride (`XMODIFY`) of `N*M`, chosen such that successive elements in each row (or RGB tuple) are 1 - 2 - 3, 4 - 5 - 6, and so on (see Figure 6-5).

The outer loop of the 2-D DMA configuration has `N*M` values (`YCOUNT=N*M`) and a negative stride (`YMODIFY`) of `1-2*N*M` chosen to instruct the DMA controller to jump from element 3 to 4, 6 to 7, and so on at the end of each inner loop.

DMA Traffic Control

The traffic control period registers and the traffic control count registers can be controlled using a command to set a value and a command to sense a value.

A data structure called `ADI_DMA_TC_SET` is defined for setting a DMA traffic control parameter. It contains fields to specify which DMA controller the command is being issued for, which of the traffic control parameters to set (`DEB`, `DCB`, `DAB`), and the value to set it to.

A similar data structure called `ADI_DMA_TC_GET` is defined for sensing a DMA traffic control parameter.

Two commands called `ADI_DMA_CMD_GET_TC` and `ADI_DMA_CMD_SET_TC` are used to set and sense the traffic control parameters. For more details on setting and sensing traffic control parameters, see "Data Structures" on page 6-55 and Table 6-3 on page 6-62.

DMA Manager API Reference

This section provides descriptions of the DMA manager API functions.

Notation Conventions

The reference pages for the API functions use the following format:

Name – Name and purpose of the function

Description – Function specification

Prototype – Required header file and functional prototype

Arguments – Description of function arguments

Return Value – Description of function return values

The DMA manager API supports the functions listed in Table 6-1.

Table 6-1. DMA Manager API Functions

Function	Description
Primary Functions	
`adi_dma_Buffer`	Provides a single or circular buffer. See "adi_dma_Buffer" on page 6-34.
`adi_dma_Close`	Closes a DMA channel. See "adi_dma_Close" on page 6-36.

Table 6-1. DMA Manager API Functions (Cont'd)

Function	Description
adi_dma_Control	Controls/queries the operation of a DMA Channel. See "adi_dma_Control" on page 6-37.
adi_dma_Init	Initializes a DMA manager. See "adi_dma_Init" on page 6-40.
adi_dma_Open	Opens a DMA channel for use. See "adi_dma_Open" on page 6-48.
adi_dma_Queue	Queues a descriptor chain. See "adi_dma_Queue" on page 6-50.
adi_dma_Terminate	Shuts down and terminates a DMA manager. See "adi_dma_Terminate" on page 6-52.
Helper Functions	
adi_dma_GetMapping	Gets the DMA Channel ID to which a peripheral is mapped. See "adi_dma_GetMapping" on page 6-39.
adi_dma_SetMapping	Sets the DMA Channel ID to which a peripheral is mapped. See "adi_dma_SetMapping" on page 6-51.
Memory DMA Functions	
adi_dma_MemoryOpen	Opens a memory DMA stream for use. See "adi_dma_MemoryOpen" on page 6-46.
adi_dma_MemoryClose	Closes a memory DMA stream. See "adi_dma_MemoryClose" on page 6-41.
adi_dma_MemoryCopy	Copies memory in a linear, one-dimensional fashion. See "adi_dma_MemoryCopy" on page 6-42.
adi_dma_MemoryCopy2D	Copies memory in a two-dimensional fashion. See "adi_dma_MemoryCopy2D" on page 6-44.

adi_dma_Buffer

Description

This function assigns a one-shot or a circular buffer to a DMA channel and configures the DMA channel according to the parameters supplied.

Prototype

```
ADI_DMA_RESULT adi_dma_Buffer(
        ADI_DMA_CHANNEL_HANDLE    ChannelHandle,
        void                      *StartAddress,
        ADI_DMA_CONFIG_REG        Config,
        u16                       XCount,
        S16                       XModify,
        u16                       YCount,
        S16                       YModify
);
```

Arguments

`ChannelHandle`	Uniquely identifies the DMA channel the buffer is assigned to and is the value returned when the DMA channel is opened
`StartAddress`	Location of the start of the filled or transmitted buffer
`Config`	DMA configuration control register for the transfer
`XCount`	Total number of words transferred in a one-dimensional buffer or the number of data elements per row in a two-dimensional buffer
`XModify`	Offset in bytes between each word transferred (1-D) or the offset in bytes between each row element (2-D)
`YCount`	Number of rows transferred
`YModify`	Offset in bytes between the last data element of one row and the first element of the next

Return Value

`ADI_DMA_RESULT_SUCCESS`	Buffer was assigned successfully.
`ADI_DMA_RESULT_BAD_HANDLE`	`ChannelHandle` does not contain a valid channel handle.
`ADI_DMA_RESULT_BAD_MODE`	DMA channel has not been opened for either single or circular buffer operation.
`ADI_DMA_RESULT_ALREADY_RUNNING`	DMA operation is in progress.

adi_dma_Close

Description

This function closes a DMA channel and releases the configuration memory for further use. Depending on the value of the WaitFlag argument, the channel is closed immediately or is closed after ongoing transfers have completed.

Prototype

```
ADI_DMA_RESULT adi_dma_Close(
        ADI_DMA_CHANNEL_HANDLE      ChannelHandle,
        u32                         WaitFlag
);
```

Arguments

ChannelHandle	Uniquely identifies the DMA channel to close and is the value returned when the DMA channel is opened
WaitFlag	If set to TRUE(1), instructs the DMA manager to wait for ongoing transfers to complete before closing the channel; otherwise, if set to FALSE(0), the channel is closed immediately, terminating any ongoing transfers.

Return Value

ADI_DMA_RESULT_SUCCESS	DMA channel successfully closed.
ADI_DMA_RESULT_BAD_HANDLE	ChannelHandle does not point to a valid channel.
ADI_DMA_RESULT_CANT_UNHOOK_INTERRUPT	Data handler and/or error handler cannot be unhooked.

adi_dma_Control

Description

The `adi_dma_Control` function controls/queries the operation of the specified DMA channel.

The function can be used in several ways:

- A single command is passed.

```
adi_dma_Control(
    ChannelHandle, ADI_DMA_CMD_SET_LOOPBACK, (void*)
TRUE);
```

- A single command-value pair is passed.

```
ADI_DMA_CMD_VALUE_PAIR cmd = {
    ADI_DMA_CMD_SET_WORD_SIZE, (void*)
ADI_DMA_WDSIZE_32BIT};
adi_dma_Control(ChannelHandle, cmd.CommandID ,cmd.Value);
```

- A single `ADI_DMA_CMD_VALUE_PAIR` structure is passed (by reference).

```
adi_dma_Control(ChannelHan-
dle,ADI_DMA_CMD_VALUE_PAIR,&cmd);
```

- A table of `ADI_COMMAND_PAIR` structures is passed. The table must have the following terminator entry to signify the end of the table of commands: `{ ADI_DMA_CMD_END, 0 }`. For example,

```
ADI_DMA_CMD_VALUE_PAIR table = {
    {ADI_DMA_CMD_SET_LOOPBACK,  (void*)LoopbackFlag},
    {ADI_DMA_CMD_SET_DATAFLOW,  (void*)TRUE},
    { ADI_DMA_CMD_END, NULL };

adi_dma_Control(ChannelHandle,ADI_DMA_CMD_TABLE,&table);
```

The set of commands that can be issued using the adi_dma_Control function is defined in "DMA Commands" on page 6-62.

Prototype

```
ADI_DMA_RESULT adi_dma_Control(
        ADI_DMA_CHANNEL_HANDLE     ChannelHandle,
        ADI_DMA_CM                 Command,
        void                       *Value
);
```

Arguments

ChannelHandle	Uniquely identifies the DMA channel the buffer is assigned to and is the value returned when the DMA channel is opened
Command	ADI_DMA_CMD enumeration value. See "DMA Commands" on page 6-62 for a full list of commands.
Value	Depending on the value for Command, this parameter is one of the following: • If Command has the value ADI_DMA_CM_VALUE_PAIR, the system issues the address of a single ADI_DMA_CMD_VALUE_PAIR element specifying the command. • If Command has the value ADI_DMA_CMD_TABLE, the system issues the address of an array of ADI_DMA_CMD_VALUE_PAIR elements specifying one or more commands. The last entry in the table must be {ADI_DMA_CMD_END,NULL}. • For any other value, Command specifies the command to be processed and Value is the associated value for the command. In the case of a command that queries a value, the value of the setting is stored at the location pointed to by the pointer Value.

Return Value

ADI_DMA_RESULT_SUCCESS	Function completed successfully.
ADI_DMA_RESULT_BAD_COMMAND	Command is invalid. Either a bad command or a specific command is not allowed in this context.
ADI_DMA_RESULT_ALREADY_RUNNING	Commands could not be performed as the channel is currently transferring data.

adi_dma_GetMapping

Description

This function is used to identify the DMA channel ID to which a DMA-compatible peripheral is mapped.

Prototype

```
ADI_DMA_RESULT adi_dma_GetMapping(
        ADI_DMA_PMAP           Peripheral,
        ADI_DMA_CHANNEL_ID     *pChannelID
);
```

Arguments

Peripheral	Peripheral ID is queried.
*pChannelID	Location where the DMA manager stores the channel ID to which the peripheral is mapped.

Return Value

ADI_DMA_RESULT_SUCCESS	Device is identified and DMA information is returned.
ADI_DMA_RESULT_BAD_PERIPHERAL	Bad peripheral value was encountered.
ADI_DMA_RESULT_NOT_MAPPED	No mapping was found for the device.

adi_dma_Init

Description

This function initializes a DMA manager.

Prototype

```
ADI_DMA_RESULT adi_dma_Init(
        void                     *pMemory,
        sizet                    MemorySize,
        u32                      *pMaxChannels
        ADI_DMA_MANAGER_HANDLE   *pManagerHandle,
        void                     *pCriticalRegionArg
);
```

Arguments

*pMemory	Pointer to memory that the DMA can use
MemorySize	Size, in bytes, of the memory provided
*pMaxChannels	Location in memory where the DMA manager stores the number of simultaneously open channels that can be supported given the memory provided
*pManagerHandle	Location in memory where the DMA manager stores the handle to the DMA manager
*pCriticalRegionArg	Parameter that the DMA manager passes to the adi_int_EnterCriticalRegion() function

Return Value

This function returns ADI_DMA_RESULT_SUCCESS if successful; any other value indicates an error. Possible errors include:

ADI_DMA_RESULT_NOMEMORY	Insufficient memory is available to initialize the DMA manager.

adi_dma_MemoryClose

Description

This function closes down a memory DMA stream, freeing up all resources used by the memory stream.

Prototype

```
ADI_DMA_RESULT adi_dma_MemoryClose(
    ADI_DMA_STREAM_HANDLE        StreamHandle,
    u32                          WaitFlag
) ;
```

Arguments

StreamHandle	Handle to the DMA memory stream
WaitFlag	If set to TRUE(1), instructs the DMA manager to wait for ongoing transfers to complete before closing down the memory stream; otherwise, if set to FALSE(0), the channel is closed immediately, terminating any transfers in progress.

Return Value

The function returns ADI_DMA_RESULT_SUCCESS if successful; any other value indicates an error. Possible errors include:

ADI_DMA_RESULT_BAD_HANDLE	StreamHandle parameter does not point to a valid memory stream.

adi_dma_MemoryCopy

Description

This function performs a one-dimensional (linear) memory copy.

Prototype

```
ADI_DMA_RESULT adi_dma_MemoryCopy(
    ADI_DMA_STREAM_HANDLE   StreamHandle,
    void                    *pDest,
    void                    *pSrc,
    u16                     ElementWidth,
    u16                     ElementCount,
    ADI_DCB_CALLBACK_FN     ClientCallback
) ;
```

Arguments

StreamHandle	Handle to the DMA memory stream
*pDest	Starting address into which memory is copied
*pDest	Starting address from which memory is copied
ElementCount	Number of elements to transfer
ElementWidth	Width of an element (in bytes); allowed values are 1, 2, and 4.
ClientCallback	Callback function called when the transfer completes. If NULL, the call to the adi_dma_MemoryCopy() function is considered synchronous and does not return to the client until the transfer has completed.

Return Value

The function returns ADI_DMA_RESULT_SUCCESS if successful; any other value indicates an error. Possible errors include:

ADI_DMA_RESULT_BAD_HANDLE	StreamHandle parameter does not point to a valid memory stream.
ADI_DMA_RESULT_IN_USE	Memory stream already has a transfer in progress.

adi_dma_MemoryCopy2D

Description

This function performs a two-dimensional memory copy.

Prototype

```
ADI_DMA_RESULT adi_dma_MemoryCopy2D(
    ADI_DMA_STREAM_HANDLE      StreamHandle,
    ADI_DMA_2D_TRANSFER        *pDest,
    ADI_DMA_2D_TRANSFER        *pSrc,
    u32                        ElementWidth,
    ADI_DCB_CALLBACK_FN        ClientCallback
);
```

Arguments

StreamHandle	Handle to the DMA memory stream
*pDest	Pointer to the structure that describes how and where the data is copied into memory
*pDest	Pointer to the structure that describes how and where the data is copied from memory
ElementWidth	Width of an element (in bytes); allowed values are 1, 2, and 4.
ClientCallback	Callback function called when the transfer completes. If NULL, the call to the adi_dma_MemoryCopy() function is considered synchronous and does not return to the client until the transfer has completed.

Return Value

The function returns ADI_DMA_RESULT_SUCCESS if successful; any other value indicates an error. Possible errors include:

ADI_DMA_RESULT_BAD_HANDLE	StreamHandle parameter does not point to a valid memory stream.
ADI_DMA_RESULT_IN_USE	Memory stream already has a transfer in progress.

adi_dma_MemoryOpen

Description

This function opens a memory DMA stream for use. Once it is opened, memory DMA transfers can be scheduled on the stream.

Prototype

```
ADI_DMA_RESULT adi_dma_MemoryOpen(
    ADI_DMA_MANAGER_HANDLE   ManagerHandle,
    ADI_DMA_STREAM_ID        StreamID,
    void                     *ClientHandle,
    ADI_DMA_STREAM_HANDLE    *pStreamHandle,
    ADI_DCB_HANDLE           DCBServiceHandle
) ;
```

Arguments

`ManagerHandle`	Handle to the DMA manager
`StreamID`	Memory stream ID that is opened.
`*ClientHandle`	Identifier defined by the client. The DMA manager includes this identifier in all DMA manager-initiated communication with the client, specifically in calls to the callback function.
`*pStreamHandle`	Pointer to a client-provided location where the DMA manager stores an identifier defined by the DMA manager. All subsequent communication initiated by the client to the DMA manager for this memory stream includes this handle.
`DCBServiceHandle`	Handle to the deferred callback service used for any memory stream events. A value of NULL means that deferred callbacks are not used and all callbacks occur at DMA interrupt time.

Return Value

The function returns ADI_DMA_RESULT_SUCCESS if successful; any other value indicates an error. Possible errors include:

ADI_DMA_RESULT_ALL_IN_USE	All channel memory is in use.
ADI_DMA_RESULT_CANT_HOOK_INTERRUPT	System cannot hook a DMA data or error interrupt.

adi_dma_Open

Description

The adi_dma_Open function opens a DMA channel for use. The DMA manager ensures the channel is not already opened and then initializes any appropriate data structures.

Prototype

```
ADI_DMA_RESULT adi_dma_Open(
   ADI_DMA_CHANNEL_ID          ChannelID
   ADI_DMA_MANAGER_HANDLE      ManagerHandle
   void                        *ClientHandle,
   ADI_DMA_CHANNEL_HANDLE      *pChannelHandle,
   ADI_DMA_MODE                Mode,
   ADI_DCB_HANDLE              DCBServiceHandle,
   ADI_DCB_CALLBACK_FN         ClientCallback
);
```

Arguments

Table 6-2. Adi_dma_Open

Argument	Explanation
ManagerHandle	Handle to the DMA manager
ChannelID	ADI_DMA_CHANNEL_ID enumeration value. See "ADI_DMA_CHANNEL_ID" on page 6-58.
*ClientHandle	Identifier defined by the client. The DMA manager includes this identifier in all DMA manager-initiated communication with the client, specifically in calls to the callback function.
*pChannelHandle	Pointer to a client-provided location where the DMA manager stores an identifier defined by the DMA manager. All subsequent communication initiated by the client to the DMA manager for this channel includes the handle to specify the channel to which it is referring.
Mode	ADI_DMA_MODE enumeration value specifying the data transfer mode used by the opened DMA channel. See "ADI_DMA_MODE" on page 6-59.
DCBServiceHandle	Handle to the deferred callback service used for the given channel. A value of NULL means that deferred callbacks are not used and all callbacks occur at DMA interrupt time.
ClientCallback	Address of a callback function defined by the application. The value passed for the ClientHandle parameter is the value supplied by the application when the channel was opened.

Return Value

The function returns ADI_DMA_RESULT_SUCCESS if the channel was successfully opened; any other value indicates an error. Possible errors include:

ADI_DMA_RESULT_ALL_IN_USE	All channel memory is in use.
ADI_DMA_RESULT_CANT_HOOK_INTERRUPT	System cannot hook a DMA data or error interrupt.

adi_dma_Queue

Description

This function queues a descriptor or chain of descriptors to the specified DMA channel.

When using descriptor chains, the descriptor is added to the end of the list of descriptors already queued to the channel, if any. The last descriptor in the chain must have its `pNext` pointer set to NULL.

Prototype

```
ADI_DMA_RESULT adi_dma_Queue(
        ADI_DMA_CHANNEL_HANDLE     ChannelHandle,
        ADI_DMA_DESCRIPTOR_HANDLE  DescriptorHandle
);
```

Arguments

`ChannelHandle`	Uniquely identifies the DMA channel that the descriptor is queued on and is the value returned when the DMA channel is opened
`DescriptorHandle`	Pointer to the first descriptor in the chain

Return Value

`ADI_DMA_RESULT_SUCCESS`	Descriptor was queued successfully.
`ADI_DMA_RESULT_BAD_HANDLE`	`ChannelHandle` does not contain a valid channel handle.
`ADI_DMA_RESULT_BAD_DESCRIPTOR`	Descriptor handle is NULL.
`ADI_DMA_RESULT_ALREADY_RUNNING`	Cannot submit additional descriptors to a channel configured for a loopback with dataflow enabled.

adi_dma_SetMapping

Description

This function maps the DMA channel ID to the given peripheral.

Prototype

```
ADI_DMA_RESULT adi_dma_SetMapping(
        ADI_DMA_PMAP             Peripheral,
        ADI_DMA_CHANNEL_ID       ChannelID
);
```

Arguments

Peripheral	Peripheral ID to which the DMA channel is mapped.
ChannelID	Channel ID that is mapped to the peripheral.

Return Value

ADI_DMA_RESULT_SUCCESS	Channel was successfully mapped.
ADI_DMA_RESULT_BAD_PERIPHERAL	Bad peripheral value was encountered.
ADI_DMA_RESULT_ALREADY_RUNNING	Mapping could not be performed as the channel is currently transferring data.

adi_dma_Terminate

Description

This function closes down all DMA activity and terminates the DMA manager.

Prototype

```
ADI_DMA_RESULT adi_dma_Terminate(
    ADI_DMA_MANAGER_HANDLE     ManagerHandle,
);
```

Arguments

ManagerHandle	Handle to the DMA manager

Return Value

The function returns ADI_DMA_RESULT_SUCCESS if successful; any other value indicates an error.

Public Data Structures, Enumerations, and Macros

This section defines the public data structures and enumerations used by the DMA manager. These data structures are made available to client applications or device driver libraries via the `adi_dma.h` header file. All types have the `ADI_DMA_` prefix to avoid ambiguity with client developer's data types.

This section contains:

Data Types

Several data types that shield the client developer from the internal implementation of the library and the details of DMA programming are used. These data types also provide an interface that is partially decoupled from the functionality offered by individual processors.

ADI_DMA_CHANNEL_HANDLE

The `ADI_DMA_CHANNEL_HANDLE` data type identifies each separate DMA channel to the DMA manager. When passed to the DMA manager function, it uniquely identifies the channel function to which it needs to refer or upon which it must operate. The DMA manager returns this handle to the application when a DMA channel is opened. All other DMA manager functions that need to identify a channel require this parameter to be passed.

ADI_DMA_DESCRIPTOR_UNION and ADI_DMA_DESCRIPTOR_HANDLE

The `ADI_DMA_DESCRIPTOR_UNION` data structure represents a union of the small descriptor, large descriptor, and descriptor array data types. The `ADI_DMA_DESCRIPTOR_HANDLE` is then a `typedef` that describes a pointer to the union. The `ADI_DMA_DESCRIPTOR_HANDLE` is passed into the `adi_dma_Queue()` function as a means to provide the function with a) a small descriptor chain, b) a large descriptor chain, or c) an array of descriptors. By using the handle/union, a single `adi_dma_Queue()` function is needed, instead of separate functions for each of the descriptor data types.

```
typedef union ADI_DMA_DESCRIPTOR_UNION {
   ADI_DMA_DESCRIPTOR_SMALL         Small;
   ADI_DMA_DESCRIPTOR_LARGE         Large;
```

```
   ADI_DMA_DESCRIPTOR_ARRAY         Array;
} ADI_DMA_DESCRIPTOR_UNION;
typedef ADI_DMA_DESCRIPTOR_UNION  *ADI_DMA_DESCRIPTOR_HANDLE;
```

ADI_DMA_STREAM_HANDLE

The ADI_DMA_STREAM_HANDLE data type identifies a memory stream to the DMA manager. When passed to the adi_dma_MemoryXXX functions, the handle uniquely identifies the memory stream onto which the DMA manager operates. The DMA manager returns this handle to the application when a DMA memory stream is opened. All other memory stream functions require this parameter to be passed.

Data Structures

The structures that define each type of descriptor and the DMA configuration control register are available in the public adi_dma.h header file. The field names follow the convention used in the *Hardware Reference* for the appropriate processor.

ADI_DMA_2D_TRANSFER

The ADI_DMA_2D_TRANSFER data structure defines the characteristics of the source or destination component of a two-dimensional memory copy.

```
typedef struct ADI_DMA_2D_TRANSFER {
    void                        *StartAddress;
    u16                         XCount;
    s16                         XModify;
    u16                         YCount;
    s16                         YModify;
} ADI_DMA_2D_TRANSFER;
```

ADI_DMA_CONFIG_REG

The ADI_DMA_CONFIG_REG type defines the structure for the DMA configuration control word. In addition, macros are provided to allow the client to set individual fields within the word.

ADI_DMA_DESCRIPTOR_ARRAY

The ADI_DMA_DESCRIPTOR_ARRAY structure defines the contents of a descriptor array element.

```
typedef struct ADI_DMA_DESCRIPTOR_ARRAY {
    void                        *StartAddress;
    ADI_DMA_CONFIG_REG          Config;
    u16                         XCount;
    s16                         XModify;
    u16                         YCount;
    s16                         YModify;
} ADI_DMA_DESCRIPTOR_ARRAY;
```

ADI_DMA_DESCRIPTOR_LARGE

The ADI_DMA_DESCRIPTOR_LARGE structure defines the contents of a large descriptor.

```
typedef struct ADI_DMA_DESCRIPTOR_LARGE {
    struct ADI_DMA_DESCRIPTOR_LARGE    *pNext;
    void                               *StartAddress;
    ADI_DMA_CONFIG_REG                 Config;
    u16                                XCount;
    s16                                XModify;
    u16                                YCount;
    s16                                YModify;
} ADI_DMA_DESCRIPTOR_LARGE;
```

ADI_DMA_DESCRIPTOR_SMALL

The ADI_DMA_DESCRIPTOR_SMALL structure defines the contents of a small descriptor.

```
typedef struct ADI_DMA_DESCRIPTOR_SMALL {
    u16                         *pNext;
    u16                         StartAddressLow;
    u16                         StartAddressHigh;
    ADI_DMA_CONFIG_REG          Config;
    u16                         XCount;
    s16                         XModify;
    u16                         YCount;
    s16                         YModify;
} ADI_DMA_DESCRIPTOR_SMALL;
```

ADI_DMA_TC_SET

The ADI_DMA_TC_SET structure is used for setting a DMA traffic control parameter. The ParameterID field specifies what type of parameter to set and is defined using the ADI_DMA_TC_PARAMETER enumeration. The ControllerID specifies which DMA controller to set, where multiple controllers are available, the first controller starting at 0. The Value field specifies the value to write.

```
typedef struct ADI_DMA_TC_SET  {
    ADI_DMA_TC_PARAMETER     ParameterID;
    u16                      ControllerID;
    u16                      Value;
} ADI_DMA_TC_SET;
```

ADI_DMA_TC_GET

The ADI_DMA_TC_GET structure is used for sensing or getting a DMA traffic control parameter. The ParameterID field specifies what type of parameter to sense and is defined using the ADI_DMA_TC_PARAMETER enumeration. The ControllerID specifies which DMA controller to sense, where multiple controllers are available, the first controller starting at 0. The Value field specifies the location where the parameter value is stored.

```
typedef struct ADI_DMA_TC_GET  {
    ADI_DMA_TC_PARAMETER     ParameterID;
    u16                      ControllerID;
    u16                      *pValue;
} ADI_DMA_TC_GET;
```

General Enumerations

Enumerations control and provide feedback for the operation of the DMA manager.

ADI_DMA_CHANNEL_ID

The ADI_DMA_CHANNEL_ID enumeration contains values for every DMA channel of the processor. This value is used in the adi_dma_Open() function to identify the channel to open. The specific enumeration values depend on the specific processor being targeted.

ADI_DMA_EVENT

The ADI_DMA_EVENT enumeration describes the types of events that can be reported to the client's callback function. Associated with the ADI_DMA_EVENT parameter is another parameter that points to the companion argument, pArg, for the event.

Value	Event	Companion Argument
ADI_DMA_EVENT_DESCRIPTOR_PROCESSED	Descriptor has completed processing or a memory stream has completed a memory copy operation.	The address of the descriptor just processed, or NULL when the event is a memory stream completion event
ADI_DMA_EVENT_INNER_LOOP_PROCESSED	A sub-buffer has completed processing.	The start address of the circular buffer
ADI_DMA_EVENT_OUTER_LOOP_PROCESSED	The entire circular buffer has completed processing.	
ADI_DMA_EVENT_ERROR_INTERRUPT	DMA error interrupt has been generated.	NULL

ADI_DMA_MODE

The `ADI_DMA_MODE` enumeration defines how a channel is to process the data to be transferred. It takes the following values:

ADI_DMA_DATA_MODE_UNDEFINED	Undefined
ADI_DMA_DATA_MODE_SINGLE	Single one-shot buffer
ADI_DMA_DATA_MODE_CIRCULAR	Single circular buffer
ADI_DMA_DATA_MODE_DESCRIPTOR_ARRAY	Array of descriptors
ADI_DMA_DATA_MODE_DESCRIPTOR_SMALL	Chain of small descriptors
ADI_DMA_DATA_MODE_DESCRIPTOR_LARGE	Chain of large descriptors

ADI_DMA_PMAP

The `ADI_DMA_PMAP` enumeration defines each of the processor's DMA-supported on-chip peripherals. This value is used to detect and set the mappings of on-chip peripherals to DMA channels using the `adi_dma_GetMapping()` and `adi_dma_SetMapping()` functions. The specific enumeration values are dependent on the specific processor being targeted.

ADI_DMA_RESULT

All public DMA manager functions return a result code of the enumeration type, `ADI_DMA_RESULT`. Possible values are:

`ADI_DMA_RESULT_SUCCESS`	Generic success is reported.
`ADI_DMA_RESULT_FAIL`	Generic failure is reported.
`ADI_DMA_RESULT_BAD_DEVICE`	Bad device information was received.
`ADI_DMA_RESULT_BAD_HANDLE`	Bad device handle was encountered.
`ADI_DMA_RESULT_BAD_DESCRIPTOR`	Bad descriptor was encountered.
`ADI_DMA_RESULT_BAD_MODE`	Bad channel mode was encountered.
`ADI_DMA_RESULT_IN_USE`	Channel is already in use.
`ADI_DMA_RESULT_ALREADY_RUNNING`	DMA is already running.
`ADI_DMA_RESULT_NO_BUFFER`	Channel has no buffer.
`ADI_DMA_RESULT_BAD_COMMAND`	Invalid `Config` item was received.
`ADI_DMA_RESULT_NO_MEMORY`	Memory to channel object cannot be assigned.

ADI_DMA_STREAM_ID

The `ADI_DMA_STREAM_ID` enumeration contains values for every DMA channel of the processor. This value is used in the `adi_dma_MemoryOpen()` function to identify which stream to open. The specific enumeration values are dependent on the specific processor being targeted.

ADI_DMA_TC_PARAMETER

The ADI_DMA_TC_PARAMETER enumeration defines the DMA traffic control parameters that can be used in the ParameterID field of an ADI_DMA_TC_SET or ADI_DMA_TC_GET data structure when passing the ADI_DMA_CMD_GET_TC and ADI_DMA_CMD_SET_TC commands to the DMA manager. Possible values are:

ADI_DMA_TC_DCB	DMA core bus
ADI_DMA_TC_DEB	DMA access bus
ADI_DMA_TC_DAB	DMA external bus
ADI_DMA_TC_MDMA	MDMA round robin

ADI_DMA_CONFIG_REG Field Values

These values are to be used to set the relevant bits in the DMA configuration word.

ADI_DMA_DMA2D

ADI_DMA_LINEAR	Linear buffer
ADI_DMA_2D	2-D DMA operation

ADI_DMA_DI_EN

ADI_DMA_DI_EN_DISABLE	Disables callbacks on completion.
ADI_DMA_DI_EN_ENABLE	Enables callbacks on completion.

ADI_DMA_DI_SEL

ADI_DMA_DI_SEL_OUTER_LOOP	Callback after completing whole buffer (default)
ADI_DMA_DI_SEL_INNER_LOOP	Callback after completing each inner loop

ADI_DMA_EN

ADI_DMA_DISABLE	Disables DMA transfer on the channel.
ADI_DMA_ENABLE	Enables DMA transfer on the channel.

ADI_DMA_WDSIZE

ADI_DMA_8BIT	8-bit words
ADI_DMA_16BIT	16-bit words
ADI_DMA_32BIT	32-bit words

ADI_DMA_WNR

ADI_DMA_READ	Transfer from memory to peripheral
ADI_DMA_WRITE	Transfer from peripheral to memory

DMA Commands

DMA channels and memory streams can be controlled via calls to the `adi_dma_Command()` function.

Table 6-3 describes the commands and values that can be issued via this function.

Table 6-3. DMA Commands

Command ID	Value	Description
ADI_DMA_CMD_TABLE	ADI_DMA_CMD_VALUE_PAIR *	Pointer to a table of commands
ADI_DMA_CMD_PAIR	ADI_DMA_CMD_VALUE_PAIR *	Pointer to a single command pair
ADI_DMA_CMD_END	NULL	Signifies end of table.

Table 6-3. DMA Commands (Cont'd)

Command ID	Value	Description
ADI_DMA_CMD_SET_LOOPBACK	TRUE/FALSE	Enables/disables loop-back.
ADI_DMA_CMD_SET_STREAMING	TRUE/FALSE	Enables/disables streaming.
ADI_DMA_CMD_SET_DATAFLOW	TRUE/FALSE	Enables/disables data-flow.
ADI_DMA_CMD_FLUSH	n/a	Flushes all buffers and descriptors on a channel.
ADI_DMA_CMD_GET_TRANSFER_STATUS	u32 *	Provides the transfer status, TRUE - in progress, FALSE - not in progress.
ADI_DMA_CMD_SET_TC	ADI_DMA_TC_SET *	Sets a traffic control (period) parameter.
ADI_DMA_CMD_GET_TC	ADI_DMA_TC_GET *	Senses a traffic control (count) parameter.

7 PROGRAMMABLE FLAG SERVICE

The programmable flag service within the system services library provides the application with an easy-to-use interface into the programmable flag (sometimes called general-purpose I/O, or GPIO) subsystem of the Blackfin processor.

This chapter contains the following sections:

Introduction

Using the capabilities of other system services, the flag service allows the client control over the direction of flags, values placed on or sensed from a flag pin, and notification of the client upon flag pin changes, via live or deferred callbacks.

The use of the flag service is dependent on the use of both the interrupt manager and the deferred callback (DCB) manager for its full operation. If callbacks are not deferred, but rather are live, the DCB manager is not required. If callbacks are not required, neither the interrupt manager nor DCB manager is required.

Currently, the flag service is available for use with the Blackfin ADSP-BF531/532/533 processors, ADSP-BF534/536/537 processors, and ADSP-BF561 processors.

In order to reduce the pin count of devices, flag pins are sometimes muxed onto the same pins as other peripherals. The flag service does not provide arbitration functionality to control pin muxing. It is the responsibility of the client program to ensure that peripherals and the flag service do not use the same pin simultaneously. For the ADSP-BF531/532/533 and ADSP-BF561 processors, this entails ensuring that the relevant peripheral control registers are correctly set. For ADSP-BF534/536/537 processors, the flag service automatically invokes the port control service to effect any pin mux changes. No user intervention is required.

For ADSP-BF531/532/533 and ADSP-BF561 processor cores, this entails ensuring that the relevant peripheral control registers are correctly set. For ADSP-BF534/536/537 processor cores, the port control registers are required to be set accordingly. The latter can be managed via the port control service within the system services library. (Note that device drivers for ADSP-BF534/536/537 processors automatically make the appropriate calls into the port control service without any user intervention.)

The flag service uses an unambiguous naming convention to safeguard against conflicts with other software libraries provided by ADI or elsewhere. To this end, all enumeration values and `typedef` statements use the `ADI_FLAG_` prefix, and functions and global variables use the lowercase `adi_flag_` equivalent.

Each function within the flag service application program interface (API) returns an error code of the type `ADI_FLAG_RESULT`. Like all system services, a return value of 0 (`ADI_FLAG_RESULT_SUCCESS`) indicates no errors. A nonzero value indicates an error. Like all system services, flag service error codes are unique from all other system services. The `adi_flag.h` include file lists all error codes that the flag service returns.

Parameter checking in the debug versions of the system services library provides a more complete test of API function parameters and for conditions that may cause errors. ADI strongly recommends that development work be done using the debug versions of the system service library, and final test and deployment be done with the release version of the library.

Operation

This section describes the overall operation of the flag service. Details on the application program interface (API) can be found later in this chapter.

Initialization

Prior to using the flag service, the client must first initialize the service. In order to initialize the service, the client passes to the initialization function, `adi_flag_Init`, a parameter that is passed to the critical region function should the flag service need to protect a critical region of code, and optionally a contiguous piece of memory that the service can use for flag callbacks.

The flag service provides a facility whereby, if so directed by the client, a callback function supplied by the client can be invoked should conditions on a flag cause an interrupt event. See "Callbacks" on page 7-6 for more information on how callbacks operate.

In order to control and manage callbacks, the flag service needs a small amount of memory to store the necessary information about each callback. The exact amount of memory is defined by a macro, ADI_FLAG_CALLBACK_MEMORY. The client provides an amount of memory equal to ADI_FLAG_CALLBACK_MEMORY times the number of callbacks that are simultaneously installed at any point in time.

For example, if the client has simultaneously installed callbacks for two flags, the client provides ADI_FLAG_CALLBACK_MEMORY * 2 bytes of memory. If flag callbacks are not used, no memory need be provided by the client.

Termination

When the client no longer requires the functionality of the flag service, the termination function, adi_flag_Terminate, is called. This function uninstalls any flag callbacks and returns any memory provided to the flag initialization function back to the client.

Flag IDs

All API functions within the flag service, other than the initialize and terminate functions, are passed a parameter that identifies the controlled flag. This parameter is of the type ADI_FLAG_ID. The include file for the flag service, adi_flag.h, defines flag IDs for each flag supported by the processor. Flag IDs are of the form ADI_FLAG_x, where x uniquely identifies the specific flag.

Flag Control Functions

The functions described in this section control operation of each flag.

adi_flag_Open

The `adi_flag_Open()` function is called prior to any of the individual flag control functions. Depending on the specific Blackfin device, this function initializes any hardware necessary for the operation of the flag. For example, on ADSP-BF534/536/537 processors, this function configures the port control logic, via the port control system service, for the flag used as a general-purpose I/O pin. On ADSP-BF561 and ADSP-BF531/532/533 processors, this function does nothing and simply returns to the caller. Refer also to "adi_flag_Open" on page 7-20.

adi_flag_Close

When a flag is no longer needed, the `adi_flag_Close()` function is called to close and shut down the flag. At present, for all Blackfin processors, this function does nothing but returns immediately to the caller. Future Blackfin devices may require this function to manipulate the hardware in some way when closing a flag. Refer also to "adi_flag_Close" on page 7-17.

adi_flag_SetDirection

Flags can be configured as inputs or outputs. The `adi_flag_SetDirection()` function is used to set the direction of a flag as either an input or an output. This function does not change the value of a flag. Refer also to "adi_flag_SetDirection" on page 7-21.

adi_flag_Set

When configured as an output, the `adi_flag_Set()` function sets the value of the flag to a logical 1, driving high. Refer also to "adi_flag_Set" on page 7-23.

adi_flag_Clear

When configured as an output, the `adi_flag_Clear()` function sets the value of the flag to a logical 0, driving low. Refer also to "adi_flag_Clear" on page 7-16.

adi_flag_Toggle

When configured as an output, the `adi_flag_Toggle()` function inverts the current value of the flag. If the flag was clear/low, this function changes the flag to set/high. If the flag was set/high, this function changes the flag to clear/low. Refer also to "adi_flag_Toggle" on page 7-24.

adi_flag_Sense

When configured as an input, the `adi_flag_Sense()` function senses the value of the flag and stores that value in the location provided by the client. If the flag is clear/low, then a value of `FALSE` is stored in the location. If the flag is set/high, then a value of `TRUE` is stored in the location. Refer also to "adi_flag_Sense" on page 7-25.

Callbacks

Like other system services, the flag service uses a callback mechanism in order to notify the client of, typically, asynchronous events.

The Blackfin processor's programmable flags can be configured to generate interrupts. The flag service provides an internal interrupt handler that is used to process interrupts from the flag hardware. This interrupt handler makes the appropriate callbacks into the client's application. When a client installs a flag callback, a parameter to the function dictates whether the callback should be made live or deferred. Live callbacks mean that the client's callback function is called at interrupt time. Deferred callbacks mean that callbacks are not made at interrupt time but rather deferred to a lower-priority using a specified deferred callback service.

When using the callback capability of the flag service, the client does not need to take any other action outside the flag service API. No calls to the interrupt manager or deferred callback service, other than initialization of those services, are required.

It is possible for clients to use all capabilities of the flag service and not use any of the callback capabilities. If callbacks are not used by the client, no memory need be provided to the flag service's initialization function.

adi_flag_InstallCallback

The `adi_flag_InstallCallback()` function is used to install a callback to a specified flag. In addition to the flag ID, the client provides the interrupt ID that the flag should generate, a wakeup flag, the type of trigger that generates the callback, the callback function address, a client handle, and deferred callback service handle. Refer also to "adi_flag_InstallCallback" on page 7-26.

Depending on the specific Blackfin processor, programmable flags can generate any one of several interrupts. (Sometimes the processor is constrained as to which flag can generate which interrupt. See the appropriate Blackfin *Hardware Reference* for details.) The peripheral ID enumerates which interrupt the flag generate.s

The wakeup flag indicates whether the processor is woken up from a low power state should the flag event occur.

The trigger type describes the event that causes the callback to occur. The following trigger types (all enumerated in the `adi_flag.h` include file) are supported:

- Level high – callback generated when the level is high
- Level low – callback generated when the level is low
- Rising edge – callback generated on the rising edge

- Falling edge – callback generated on the falling edge
- Both edges – callback generated on both the rising and falling edge

The callback function address specifies a callback function of the type `ADI_DCB_CALLBACK_FN` (see the deferred callback service for more information on this data type). When invoked, the callback function is passed three parameters:

- `ClientHandle` – a value provided by the client when the callback was installed
- `ADI_FLAG_EVENT_CALLBACK` – indicates a flag callback event
- `FlagID` – the flag ID of the flag that generated the callback

When the deferred callback service handle parameter passed to the `adi_flag_InstallCallback` function is NULL, the callback is executed live, meaning it is invoked at interrupt time. If the deferred callback service handle parameter is non-NULL, the flag service uses the specified deferred callback service to invoke the callback.

A single callback function can be used and installed for any number of flags; the callback function can use the `FlagID` parameter to determine which flag generated the callback. Note, however, that only one callback should be installed for a given flag.

This function does not alter flag control, such as direction.

adi_flag_RemoveCallback

The `adi_flag_RemoveCallback()` function is used to remove a callback from a specified flag. This function disables interrupt generation for the flag and removes the callback from its internal tables. Unless reinstalled, no further callbacks occur for the specified flag. After calling this function, the memory freed by removing the callback is available for the flag service to use for the next callback that is installed. This function does not alter flag control, such as direction. Refer also to "adi_flag_RemoveCallback" on page 7-28.

adi_flag_SuspendCallbacks

The `adi_flag_SuspendCallbacks()` function is used to temporarily suspend callbacks for a given flag but does not uninstall the callback. This function is typically used in conjunction with the `adi_flag_ResumeCallbacks` function. Refer also to "adi_flag_SuspendCallbacks" on page 7-29.

adi_flag_ResumeCallbacks

The `adi_flag_ResumeCallbacks()` function is used to re-enable callbacks that were suspended by the `adi_flag_SuspendCallbacks` function. Refer also to "adi_flag_ResumeCallbacks" on page 7-30.

adi_flag_SetTrigger

The `adi_flag_SetTrigger()` function sets the condition on a flag that triggers a callback. This function is not typically called by clients as setting the trigger condition is taken care of automatically by the `adi_flag_InstallCallback` function. This function is provided as a convenience for users who want an extra measure of control on callbacks. Refer also to "adi_flag_SetTrigger" on page 7-31.

Coding Example

This section describes the code required to implement a simple example using the flag service. This example initializes the flag service, configures one flag for input, and configures another flag for output. The example illustrates how the output flag is controlled and then illustrates how a callback function is used to sense changes on a flag. All flag service functions return an error code. In practice, this error code should be checked to ensure the function completed successfully. For the purposes of this example only, the return value is not checked.

Initialization

Prior to using the flag service, it must be initialized. The following fragment initializes the service and provides the service with memory for one callback function.

```
static u8 FlagServiceData[ADI_FLAG_CALLBACK_MEMORY * 1];
                          // memory for service

ADI_FLAG_RESULT Result;   // return value
u32 ResponseCount;        // number of callbacks supported

Result = adi_flag_Init(FlagServiceData, sizeof(FlagServiceData),
                       &ResponseCount, NULL);
```

Upon completing this function, the flag service is initialized and is ready for use.

Opening a Flag

After the service is initialized, any flags used can be opened. In this example, two flags are used.

```
Result = adi_flag_Open(ADI_FLAG_PF0);

Result = adi_flag_Open(ADI_FLAG_PF1);
```

The `adi_flag_Open` function takes any action necessary to configure the processor hardware for use as a programmable flag.

Setting Flag Direction

After the flags are opened, they must be set to the proper direction. In this example, one flag is configured for input and one for output.

```
Result = adi_flag_SetDirection(ADI_FLAG_PF0,
                                ADI_FLAG_DIRECTION_INPUT);

Result = adi_flag_SetDirection(ADI_FLAG_PF1,
                                ADI_FLAG_DIRECTION_OUTPUT);
```

Once the flag direction has been established, the flag can be controlled.

Controlling an Output Flag

After a flag is configured for the output direction, its value can be set with any of the following functions.

```
Result = adi_flag_Set(ADI_FLAG_PF0);
                   // sets output value to logical high (1)

Result = adi_flag_Clear(ADI_FLAG_PF0);
                   // sets output value to logical low (0)

Result = adi_flag_Toggle(ADI_FLAG_PF0);
                   // toggles from current value
```

The first call sets the value of the flag to a logical high, and the second call sets the flag to a logical low. The third call toggles the current value of the flag—if logical low, it changes to a logical high value; if logical high, it changes to a logical low value.

Sensing the Value of a Flag

The application can sense the value of a flag, regardless of whether the flag has been configured as an input or an output. The following fragment illustrates how a flag value is sensed.

```
u32 Value;         // location where flag value is stored
Result = adi_flag_Sense(ADI_FLAG_PF0, &Value);
                   // senses the flag value
if (Value == TRUE) {
                   // flag is set to logical high
} else {
                   // flag is set to logical low }
```

The above fragment illustrates how a flag value can be sensed in a polled type method. Alternatively, a callback function can be used to alert the application when an event, such as a flag changing value, has occurred.

Installing a Callback Function

To avoid polling and instead invoke a callback function when a pin state changes, the application should install a callback function. The following fragment illustrates how to install a callback function and the actual callback function.

```
...
Result = adi_flag_InstallCallback(ADI_FLAG_PF1, ADI_INT_PFA,
                  ADI_FLAG_TRIGGER_LEVEL_HIGH,
                  TRUE, (void *)0x12345678, NULL, Callback);
...
```

```
void Callback(void *ClientHandle, u32 Event, void *pArg) {
     // ClientHandle = 0x12345678
     // Event = ADI_FLAG_EVENT_CALLBACK
     switch ((ADI_FLAG_ID)pArg) {
     case ADI_FLAG_PF1:
               // do processing when PF1 changes state break;
     }
}
```

When the callback function is invoked, the `ClientHandle` parameter is the value that is given when the callback is installed (in this case, `0x12345678`), the `Event` is the `ADI_FLAG_EVENT_CALLBACK` value, and the `pArg` parameter contains the flag ID that triggered the callback.

Suspending and Resuming Callbacks

If the application needs to temporarily suspend callback processing, the following fragment illustrates how to do it.

```
Result = adi_flag_SuspendCallbacks(ADI_FLAG_PF1);
```

The callback function for that flag is no longer called when the trigger condition occurs. The following fragment illustrates how to resume callback processing.

```
Result = adi_flag_ResumeCallbacks(ADI_FLAG_PF1);
```

Now the callback function will again be invoked when the trigger condition occurs.

Removing Callbacks

If an application no longer needs the callback, it removes the callback with the following call.

```
Result = adi_flag_RemoveCallback(ADI_FLAG_PF1);
```

The callback function is no longer invoked, and the callback function itself is removed from the flag service. The memory used to manage that callback is now available to the flag service to use for another callback function should another callback be installed.

Termination

When the functionality provided by the flag service is no longer required, the application terminates the service. The following fragment terminates the flag service.

```
ADI_FLAG_RESULT Result;       // return value

Result = adi_flag_Terminate();
```

After termination, any memory provided to the flag service during installation is freed up for reuse by the application.

Flag Service API Reference

This section provides the flag service API.

The information in this section was accurate at the time this document was created. However, always check the include file for the flag service, `adi_flag.h`, for the most up-to-date information.

Notation Conventions

The reference pages for the API functions use the following format:

Name – Name and purpose of the function

Description – Function specification

Prototype – Required header file and functional prototype

Arguments – Description of function arguments

Return Value – Description of function return values

adi_flag_Clear

Description

The `adi_flag_Clear` function sets the value of the flag to a logical 0, driving low.

Prototype

```
void adi_flag_Clear(
        ADI_FLAG_ID         FlagID
);
```

Arguments

`FlagID`	Enumerator value that uniquely identifies the flag to close

Return Value

`ADI_FLAG_RESULT_SUCCESS`	Function completed successfully.
Any other value	Error has occurred. See "ADI_FLAG_RESULT" on page 7-33 for a list of return codes.

adi_flag_Close

Description

The adi_flag_Close function is called when a particular flag is no longer needed by the application. At present, this function does nothing but returns immediately to the caller. Future Blackfin devices may require this function manipulate the hardware in some way when closing a flag.

Prototype

```
void adi_flag_Close(
        ADI_FLAG_ID         FlagID
);
```

Arguments

FlagID	Enumerator value that uniquely identifies the flag to close

Return Value

ADI_FLAG_RESULT_SUCCESS	Function completed successfully.
Any other value	Error has occurred. See "ADI_FLAG_RESULT" on page 7-33 for a list of return codes.

adi_flag_Init

Description

The adi_flag_Init function provides and initializes memory for the flag service. This function should only be called once per core. If called by more than one core, provide separate memory areas.

Prototype

```
ADI_FLAG_RESULT adi_flag_Init(
        void                          *pMemory,
        const size_t                  MemorySize,
        u32                           *pMaxEntries,
        void                          *pEnterCriticalParam
);
```

Arguments

pMemory	Pointer to an area of memory used to hold the data required by the flag service
MemorySize	Size, in bytes, of memory supplied for the flag service data
*pMaxEntries	On return, holds the maximum number of simultaneously active callback functions that can be supported using the supplied memory
*pEnterCriticalParam	Handle to data area containing critical region data. This is passed to adi_int_EnterCriticalRegion where it is used internally of the module. See "Interrupt Manager" on page 2-1 for further details.

Return Value

ADI_FLAG_RESULT_SUCCESS	Flag service was successfully initialized.
Any other value	Error has occurred. See “ADI_FLAG_RESULT” on page 7-33 for a list of return codes.

adi_flag_Open

Description

The `adi_flag_Open` function configures any hardware necessary for the specified flag to operate as a general-purpose I/O pin. Depending on the specific Blackfin device, this function initializes any hardware necessary for the operation of the flag. For example, on ADSP-BF534/536/537 processors, this function configures the port control logic, via the port control system service, for the flag to be used as a general-purpose I/O pin. On ADSP-BF531/532/533 and ADSP-BF561 processors, this function does nothing and simply returns to the caller.

Prototype

```
void adi_flag_Open(
        ADI_FLAG_ID      FlagID
);
```

Arguments

`FlagID`	Enumerator value that uniquely identifies the flag to open

Return Value

`ADI_FLAG_RESULT_SUCCESS`	Function completed successfully.
Any other value	Error has occurred. See "ADI_FLAG_RESULT" on page 7-33 for a list of return codes.

adi_flag_SetDirection

Description

The `adi_flag_SetDirection` function sets the flag direction as an input or an output. If set as an input, any on-chip input buffer for the flag is also enabled. If set as an output, any on-chip input buffer for the flag is disabled.

Prototype

```
void adi_flag_SetDirection(
        ADI_FLAG_ID                FlagID,
        ADI_FLAG_DIRECTION         Direction
);
```

Arguments

`FlagID`	Enumerator value that uniquely identifies the flag to control
`Direction`	Direction to which the flag is configured

Return Value

`ADI_FLAG_RESULT_SUCCESS`	Function completed successfully.
Any other value	Error has occurred. See "ADI_FLAG_RESULT" on page 7-33 for a list of return codes.

adi_flag_Terminate

Description

The `adi_flag_Terminate` function closes the flag service. Any installed callbacks are removed, and all memory provided at initialization is returned. Once terminated, the initialization function must be called again before using any of the flag service functions.

Prototype

```
ADI_FLAG_RESULT adi_flag_Terminate(
                void
);
```

Arguments

None.

Return Value

`ADI_FLAG_RESULT_SUCCESS`	Function completed successfully.
Any other value	Error has occurred. See "ADI_FLAG_RESULT" on page 7-33 for a list of return codes.

adi_flag_Set

Description

The `adi_flag_Set` function sets the value of the flag to a logical 1, driving high.

Prototype

```
void adi_flag_Set(
        ADI_FLAG_ID                FlagID
);
```

Arguments

`FlagID`	Enumerator value that uniquely identifies the flag to control

Return Value

`ADI_FLAG_RESULT_SUCCESS`	Function completed successfully.
Any other value	Error has occurred. See "ADI_FLAG_RESULT" on page 7-33 for a list of return codes.

adi_flag_Toggle

Description

The adi_flag_Toggle function inverts the current value of the flag. If the flag is a logical 1 (driving high), this function makes the flag a logical 0 (driving low). If the flag is a logical (0 driving low), this function makes the flag a logical 1 (driving high).

Prototype

```
void adi_flag_Toggle(
        ADI_FLAG_ID                FlagID
);
```

Arguments

FlagID	Enumerator value that uniquely identifies the flag to control

Return Value

ADI_FLAG_RESULT_SUCCESS	Function completed successfully.
Any other value	Error has occurred. See "ADI_FLAG_RESULT" on page 7-33 for a list of return codes.

adi_flag_Sense

Description

The `adi_flag_Sense` function senses the value of a flag. The function stores the value `TRUE` in the provided location if the flag is a logical 1. Otherwise, the function stores the value `FALSE` in the provided location.

Prototype

```
void adi_flag_Sense(
        ADI_FLAG_ID                 FlagID,
        u32                         pValue
);
```

Arguments

`FlagID`	Enumerator value that uniquely identifies the flag to control
`pValue`	Pointer to location where the value of the flag is stored

Return Value

`ADI_FLAG_RESULT_SUCCESS`	Function completed successfully.
Any other value	Error has occurred. See "ADI_FLAG_RESULT" on page 7-33 for a list of return codes.

adi_flag_InstallCallback

Description

The adi_flag_InstallCallback function installs a callback function that is invoked should the specified trigger condition for the given flag occur. Note that the function provided by the caller is a callback function, not an interrupt handler. This function does not alter the flag values, direction, and so on.

Prototype

```
ADI_FLAG_RESULT adi_flag_InstallCallback(
        ADI_FLAG_ID                 FlagID,
        ADI_INT_PERIPHERAL_ID       PeripheralID,
        ADI_FLAG_TRIGGER            Trigger,
        u32                         WakeupFlag,
        void                        *ClientHandle,
        ADI_DCB_HANDLE              DCBHandle,
        ADI_DCB_CALLBACK_FN         ClientCallback
);
```

Arguments

`FlagID`	Enumerator value that uniquely identifies which flag the callback is assigned
`PeripheralID`	Peripheral ID that specifies the system interrupt for the flag to use (see interrupt manager and adi_int.h.)
`Trigger`	Trigger condition that generates the callback
`WakeupFlag`	Flag indicating if the processor has woken up from a low power state if the trigger occurs
`ClientHandle`	Identifier defined and supplied by the client. This value is passed to the callback function.
`DCBHandle`	Either NULL if using live callbacks or the handle to the deferred callback service that is used for callbacks
`ClientCallback`	Address of the client's callback function

Return Value

`ADI_FLAG_RESULT_SUCCESS`	Flag service was successfully initialized.
Any other value	Error has occurred. See "ADI_FLAG_RESULT" on page 7-33 for a list of return codes.

adi_flag_RemoveCallback

Description

The adi_flag_RemoveCallback function removes the callback from the specified flag and disables the generation of the interrupt that triggers the callback. This function does not alter the flag values, direction, and so on.

Prototype

```
void adi_flag_RemoveCallback(
        ADI_FLAG_ID                FlagID
);
```

Arguments

FlagID	Enumerator value that uniquely identifies the flag whose callback is removed

Return Value

ADI_FLAG_RESULT_SUCCESS	Function completed successfully.
Any other value	Error has occurred. See "ADI_FLAG_RESULT" on page 7-33 for a list of return codes.

adi_flag_SuspendCallbacks

Description

The `adi_flag_SuspendCallbacks` function temporarily suspends callbacks for a given flag but does not uninstall the callback. This function is typically used in conjunction with the `adi_flag_ResumeCallbacks` function. This function simply disables the interrupt that causes the callback to occur.

Prototype

```
void adi_flag_SuspendCallbacks(
        ADI_FLAG_ID                FlagID,
        ADI_INT_PERIPHERAL_ID      PeripheralID
);
```

Arguments

`FlagID`	Enumerator value that uniquely identifies the flag whose callbacks are suspended
`PeripheralID`	Peripheral ID that specifies the system interrupt for the flag to use (see interrupt manager and adi_int.h.)

Return Value

`ADI_FLAG_RESULT_SUCCESS`	Function completed successfully.
Any other value	Error has occurred. See "ADI_FLAG_RESULT" on page 7-33 for a list of return codes.

adi_flag_ResumeCallbacks

Description

The `adi_flag_ResumeCallbacks` function resumes callback generation that was temporarily suspended by the `adi_flag_SuspendCallbacks` function. This function simply re-enables the interrupt that causes the callback to occur.

Prototype

```
void adi_flag_ResumeCallbacks(
        ADI_FLAG_ID                FlagID,
        ADI_INT_PERIPHERAL_ID      PeripheralID
);
```

Arguments

`FlagID`	Enumerator value that uniquely identifies the flag whose callbacks are resumed
`PeripheralID`	Peripheral ID that specifies the system interrupt for the flag to use (see interrupt manager and adi_int.h.)

Return Value

`ADI_FLAG_RESULT_SUCCESS`	Function completed successfully.
Any other value	Error has occurred. See "ADI_FLAG_RESULT" on page 7-33 for a list of return codes.

adi_flag_SetTrigger

Description

The `adi_flag_SetTrigger` function sets the trigger condition that generates a callback. This function is not typically called by clients, as setting the trigger condition is taken care of automatically by the `adi_flag_InstallCallback` function.

This function is provided as a convenience for users who want an extra measure of control on callbacks. The function can also be used to change the trigger conditions for a callback without removing and then reinstalling the callback.

Prototype

```
void adi_flag_SetTrigger(
        ADI_FLAG_ID                FlagID,
        ADI_FLAG_TRIGGER           Trigger
);
```

Arguments

`FlagID`	Enumerator value that uniquely identifies the flag whose callbacks are resumed
`Trigger`	Trigger condition that generates the callback

Return Value

`ADI_FLAG_RESULT_SUCCESS`	Function completed successfully.
Any other value	Error has occurred. See "ADI_FLAG_RESULT" on page 7-33 for a list of return codes.

Public Data Types, Enumerations, and Macros

This section defines the public data structures and enumerations used by the flag service.

Always check the include file for the flag service, `adi_flag.h`, for the most up-to-date information.

ADI_FLAG_ID

The `ADI_FLAG_ID` enumeration type uniquely defines each flag in the processor being targeted. To the client application, flag IDs are simply values that identify a specific flag; however, each flag ID actually consists of two pieces of information.

The upper 16 bits of the enumeration is the bit position within the port that corresponds to that flag. The lower 16 bits is the offset to the flags system registers that control the flag. A macro is provided that creates a flag ID, given a bit position and register offset. Macros are also provided to extract the bit position and register offset when given a flag ID.

Applications rarely, if ever, need access to these macros; however, they are provided in the `adi_flag.h` file for reference. Applications typically use only the completed flag ID value. The preset enumeration values are too numerous to list here, but take the form `ADI_FLAG_Pxy`, where “`x`” is the port ID and “`y`” is the index into the port for the flag. Refer to `adi_flag.h` for further details.

Associated Macros

These macros are defined for internal use by the flag service.

ADI_FLAG_CREATE_FLAG_ID	Creates a flag ID given a bit position and register offset
ADI_FLAG_GET_BIT	Gets the bit position given a flag ID
ADI_FLAG_GET_OFFSET	Gets the register offset given a flag ID
ADI_FLAG_GET_MASK	Creates a mask for a given flag ID that can be used to manipulate hardware control registers for the given flag.

ADI_FLAG_RESULT

Each API function of the flag service returns an ADI_FLAG_RESULT enumeration as a return code. As with all system services, generic success is defined as 0 and generic failure is defined as 1. This allows the calling function to quickly evaluate the return code for a zero or nonzero value. All detailed result codes for the flag service begin with the value ADI_FLAG_ENUMERATION_START for easy identification.

Result code	Description
ADI_FLAG_RESULT_SUCCESS=0	Generic success = 0
ADI_FLAG_RESULT_FAILED=1	Generic failure = 1
ADI_FLAG_RESULT_INVALID_FLAG_ID	(0x80001) invalid flag ID
ADI_FLAG_RESULT_INTERRUPT_MANAGER_ERROR	(0x80002) error returned from interrupt manager
ADI_FLAG_RESULT_ERROR_REMOVING_CALLBACK	(0x80003) no callback installed for given ID
ADI_FLAG_RESULT_ALL_IN_USE	(0x80004) all flag slots in use
ADI_FLAG_RESULT_PORT_CONTROL_ERROR	(0x80005) error within port control

ADI_FLAG_RESULT_NOT_CAPABLE	(0x80006) given flag not capable of function requested
ADI_FLAG_RESULT_TRIGGER_TYPE_NOT_SUPPORTED	(0x80007) trigger type is not supported
ADI_FLAG_RESULT_CANT_MAP_FLAG_TO_INTERRUPT	(0x80008) cannot map flag to given interrupt peripheral ID
ADI_FLAG_RESULT_NOT_MAPPED_TO_INTERRUPT	(0x80009) flag not mapped to interrupt
ADI_FLAG_RESULT_CALLBACK_NOT_INSTALLED	(0x8000a) no callback is installed for given flag
ADI_FLAG_RESULT_BAD_CALLBACK_MEMORY_SIZE	(0x8000b) ADI_FLAG_CALLBACK_MEMORY macro is invalid (internal error)

ADI_FLAG_EVENT

The ADI_FLAG_EVENT enumeration defines the type of callback event that occurred. There is only one value, ADI_FLAG_EVENT_CALLBACK. This enumeration type is different from all other event types for system services—a single callback function can be used for any service, regardless of the event it processes. Event codes for the flag service begin with the value ADI_FLAG_ENUMERATION_START, for easy identification.

Event code	Description
ADI_FLAG_EVENT_CALLBACK	The trigger condition for the specified flag occurred.

ADI_FLAG_TRIGGER

The ADI_FLAG_TRIGGER enumeration type is used to specify the condition that, when triggered, causes the application's callback function to be invoked.

ADI_FLAG_TRIGGER_LEVEL_HIGH	Flag set when voltage on pin is at recognized 'digital' high level
ADI_FLAG_TRIGGER_LEVEL_LOW	Flag set when voltage on pin is at recognized 'digital' low level
ADI_FLAG_TRIGGER_RISING_EDGE	Flag set when voltage on pin rises from low to high level (rising edge)
ADI_FLAG_TRIGGER_FALLING_EDGE	Flag set when voltage on pin falls from high to low level (falling edge)
ADI_FLAG_TRIGGER_BOTH_EDGE	Flag set on both rising and falling edges

ADI_FLAG_DIRECTION

The ADI_FLAG_DIRECTION enumeration defines the direction (input or output) for a flag pin.

ADI_FLAG_DIRECTION_INPUT	Flag is configured as an input.
ADI_FLAG_DIRECTION_OUTPUT	Flag is configured as an output.

8 TIMER SERVICE

The timer service, within the system services library, provides the application with an easy-to-use interface into the core timers, watchdog timers, and general-purpose timers of the Blackfin processor.

This chapter contains the following sections:

Introduction

Using the capabilities of other system services, the timer service allows the client to control and coordinate the all timers in a consistent fashion, regardless of processor derivative. The service also provides the means for clients to install callback functions that are notified upon timer expirations.

Use of the timer service is dependent on the use of both the interrupt manager and the deferred callback (DCB) manager for its full operation. If callbacks are not deferred, but rather are live, the DCB manager is not required. If callbacks are not required, neither the interrupt manager nor DCB manager is required.

In order to reduce the pin count of devices, timer pins are sometimes muxed onto the same pins as other peripherals. The timer service does not provide arbitration functionality to control pin muxing. It is the responsibility of the client program to ensure that peripherals and the timer service do not use the same pin simultaneously. For ADSP-BF531/532/533 and ADSP-BF561 processors, this entails ensuring that the relevant peripheral control registers are correctly set. For ADSP-BF534/536/537 processors, the timer service automatically invokes the port control service to affect any pin mux changes. No user intervention is required.

The timer service uses an unambiguous naming convention to safeguard against conflicts with other software libraries provided by Analog Devices or elsewhere. All enumeration values and `typedef` statements use the `ADI_TMR_` prefix, and functions and global variables use the lowercase `adi_tmr_` equivalent.

Each function within the timer service application program interface (API) returns an error code of the type `ADI_TMR_RESULT`. Like all system services, a return value of 0 (`ADI_TMR_RESULT_SUCCESS`) indicates no errors. A nonzero value indicates an error. Like all system services, timer service error codes are unique from all other system services. The `adi_tmr.h` include file lists all error codes that the timer service returns.

Parameter checking in the debug versions of the system services library provides a more complete test of API function parameters and for conditions that may cause errors. Analog Devices strongly recommends that development work be done using the debug versions of the system service library, while final test and deployment be done with the release version of the library.

Operation

This section describes the overall operation of the timer service. Details on the application programming interface (API) can be found later in this chapter.

Initialization

Prior to using the timer service, the client must first initialize the service. In order to initialize the service, the client passes to the initialization function, `adi_tmr_Init()`, a parameter is passed to the critical region function should the timer service need to protect a critical region of code, and optionally a contiguous piece of memory that the service can use for flag callbacks.

The timer service provides a facility where, if so directed by the client, a callback function supplied by the client can be invoked should a timer expire. See the "Callbacks" on page 8-7 for more information on how callbacks operate. Unlike some other services in which the client provides memory to the service for use by the service, the timer service requires no additional memory.

Termination

When the client no longer requires the functionality of the timer service, the termination function, `adi_tmr_Terminate()`, is called. This function uninstalls any installed timer callbacks and closes any open timers.

Timer IDs

All API functions within the timer service, other than the initialize and terminate functions, are passed a parameter that identifies the timer(s) to be controlled. The include file for the timer service, `adi_tmr.h`, defines the timer IDs for each timer supported by the processor. The timer ID parameter is defined as a `u32` type, but it is not a simple enumeration value. The timer ID is actually a complex value that contains information specific to the timer and also allows them to be ORed together so that multiple timers can be enabled and disabled simultaneously.

Basic Timer Functions

The functions described in this section are common to all types of timers: general-purpose timers, core timers, and watchdog timers. Any individual timer ID, regardless whether it is a general-purpose timer ID, core timer ID, or watchdog timer ID, can be passed to these functions.

adi_tmr_Open

The `adi_tmr_Open()` function is called to open the timer. Depending on the specific Blackfin device, this function initializes the hardware necessary for the operation of the timer. This function also resets the timer to its default settings. Refer also to "adi_tmr_Open" on page 8-17.

adi_tmr_Close

When a timer is no longer needed, the `adi_tmr_Close()` function is called to close and shut down the timer. Presently for all Blackfin processors, this function does nothing but returns immediately to the caller. Future Blackfin processors may require this function to manipulate the hardware in some way when closing a timer. Refer also to "adi_tmr_Close" on page 8-19.

adi_tmr_Reset

Should an application need to reset the timer to the default settings at a time other than when it is opened, use the `adi_tmr_Reset()` function. The configuration register for the timer is reset to its power-up value, the error status is cleared, and so on. Refer also to "adi_tmr_Reset" on page 8-20.

General-Purpose Timer Functions

The functions described in this section are for general-purpose timers only. These functions return an error if they are passed other types of timer IDs, such as core timer IDs or watchdog timer IDs.

adi_tmr_GPControl

The `adi_tmr_GPControl()` function configures a general-purpose timer. This function is passed the timer ID of the timer being controlled, a command ID specifying the parameter of the function being addressed, and a command-specific parameter. The list of command IDs applicable to general-purpose timers and the corresponding command-specific parameters are described in "ADI_TMR_GP_CMD" on page 8-35. Refer also to "adi_tmr_GPControl" on page 8-23.

adi_tmr_GPGroupEnable

The `adi_tmr_GPGroupEnable()` function enables or disables a single general-purpose timer or a group of general-purpose timers. This function is passed a parameter that is either a single general-purpose timer ID or an ORing of any number of general-purpose timer IDs, and a flag that indicates whether the group of timers is enabled (a value of `TRUE`) or disabled (a value of `FALSE`).

The function uses best efforts to simultaneously enable or disable the group of timers. If the underlying hardware of the specific Blackfin device allows the timers to be controlled simultaneously, the function takes the necessary action to simultaneously enable or disable the timers. If the underlying hardware does not allow the specified timers to be controlled simultaneously, the function uses best efforts to enable or disable the timers as quickly as possible. Refer also to "adi_tmr_GPGroupEnable" on page 8-24.

Core Timer Functions

The functions described in this section are used for the core timer only.

adi_tmr_CoreControl

The `adi_tmr_CoreControl()` function is used to configure the core timer. Analogous to the general-purpose timer control function, this function is passed a command ID specifying the parameter of the function that is being addressed, and a command-specific parameter. The list of command IDs applicable to the core timer and the corresponding command-specific parameters are described in "ADI_TMR_CORE_CMD" on page 8-33. Refer also to "adi_tmr_CoreControl" on page 8-21.

Watchdog Timer Functions

The functions described in this section are used for the watchdog timer only.

adi_tmr_WatchdogControl

The `adi_tmr_WatchdogControl()` function configures the watchdog timer. Analogous to the general-purpose timer and core timer control functions, this function is passed a command ID specifying the parameter of the function being addressed, and a command-specific parameter. Refer also to "adi_tmr_WatchdogControl" on page 8-22.

The list of command IDs applicable to the watchdog timer and the corresponding command-specific parameters are described in "ADI_TMR_WDOG_CMD" on page 8-34.

Peripheral Timer Functions

The functions described in this section are used for the general-purpose timers and watchdog timers only. Passing a core timer ID to these functions results in an error being returned to the caller.

adi_tmr_GetPeripheralID

The `adi_tmr_GetPeripheralID()` function can be called to identify the peripheral ID for the specified timer. While not normally required, this function may be useful if finer granularity of interrupt control logic than what is provided by the timer service is required. The peripheral ID value can be passed to functions in the interrupt service. Note that the core timer does not have an associated peripheral ID because the core timer mapping to an IVG level is fixed. Regardless, the core timer ID may still be passed to this function, and the function does not return an error. Refer also to "adi_tmr_GetPeripheralID" on page 8-29.

Callbacks

Like other system services, the timer service uses a callback mechanism in order to notify the client of asynchronous events, such as a timer expiring. Callbacks can be used on all types of timers: general-purpose timers, core timers, and watchdog timers.

The Blackfin processor's timers can be configured to generate interrupts. The timer service provides an internal interrupt handler that processes interrupts from the timer hardware. This interrupt handler makes the appropriate callbacks into the client's application. When a client installs a timer callback, a parameter to the function dictates if the callback is live or deferred. Live callbacks mean that the client's callback function is called at interrupt time. Deferred callbacks mean that callbacks are not made at interrupt time but rather deferred to a lower priority using a specified deferred callback service.

When using the callback capability of the timer service, the client does not need to take any other action outside the timer service API. No calls to the interrupt manager or deferred callback service, other than initialization of those services, are required.

Note that it is possible for clients to use all capabilities of the timer service and not use any of the callback capabilities.

adi_tmr_InstallCallback

The `adi_tmr_InstallCallback()` function is used to install a callback to a specified timer. In addition to the timer ID, the client provides a wakeup flag, the callback function address, a client handle, and a deferred callback service handle.

The wakeup flag indicates whether the processor is awake from a low-power state, should the timer event occur.

The callback function address specifies a callback function of the type `ADI_DCB_CALLBACK_FN` (see "Deferred Callback Manager" for more information). When invoked, the callback function is passed the following three parameters:

- `ClientHandle` – a value provided by the client when the callback is installed
- `ADI_TMR_EVENT_TIMER_EXPIRED` – indicates a timer callback event
- `TimerID` – the timer ID of the timer that generates the callback

When the deferred callback service handle parameter passed to the `adi_tmr_InstallCallback` function is NULL, the callback is executed live, meaning it is invoked at interrupt time. If the deferred callback service handle parameter is non-NULL, the timer service uses the specified deferred callback service to invoke the callback.

A single callback function can be used and installed for any number of timers; the callback function can use the `TimerID` parameter to determine which timer generated the callback. Note, however, that only one callback should be installed for a given timer.

This function does not alter timer control (such as direction) at all. Refer also to "adi_tmr_InstallCallback" on page 8-26.

adi_tmr_RemoveCallback

The `adi_tmr_RemoveCallback()` function is used to remove a callback from a specified timer. This function disables interrupt generation for the timer and removes the callback from its internal tables. Unless reinstalled, no further callbacks occur for the specified timer. This function does not alter timer control in any way. Refer also to "adi_tmr_RemoveCallback" on page 8-28.

Coding Example

This section provides code samples, illustrating how to access and use the functionality provided by the timer service. This example initializes the timer service, configures a couple of general-purpose timers, the core timer, and the watchdog timer. The use of callbacks is also illustrated. All timer service functions return an error code. In practice, check this error code to ensure the function completed successfully. For the purposes of this example only, the return value is not checked.

Operation

Initialization

Prior to using the timer service, it must be initialized. The following fragment initializes the service.

```
ADI_TMR_RESULT Result;              // return value

Result = adi_tmr_Init(NULL);
```

Upon completion of this function, the timer service is initialized and ready for use. This function does not alter the timers in any way but simply initialized internal data structures.

Opening a Timer

After the service is initialized, any timers that you need to use can be opened. In this example, two general-purpose timers, the core timer, and watchdog timer are opened

```
Result = adi_tmr_Open(ADI_TMR_GP_TIMER_0);
Result = adi_tmr_Open(ADI_TMR_GP_TIMER_1);
Result = adi_tmr_Open(ADI_TMR_CORE_TIMER);
Result = adi_tmr_Open(ADI_TMR_WDOG_TIMER);
```

The open function opens the timer for use and resets the timer to its power-up values, clearing any pending status, and so on.

Configuring a Timer

After the timer is opened, the timer can be configured. The `adi_tmr_GPControl()`, `adi_tmr_CoreControl()` and `adi_tmr_WatchdogControl()` functions are used to configure general-purpose timers, core timers, and the watchdog timers, respectively.

Each of these functions are provided with a command ID, typically specifying the parameter to control and a value for the parameter. (Note that the general-purpose control function also is passed a timer ID specifying the timer being controlled.) Commands to timers can be given individually or collectively as a table.

The following fragment illustrates both methods.

```
ADI_TMR_CORE_CMD_VALUE_PAIR CoreTable [] = {
      {ADI_TMR_CORE_CMD_SET_COUNT,        (void *)0x12345678 },
      { ADI_TMR_CORE_CMD_SET_PERIOD,      (void *)0xabcdef },
      { ADI_TMR_CORE_CMD_SET_SCALE,       (void *)0x10 },
      { ADI_TMR_CORE_CMD_SET_ACTIVE_MODE, (void *)TRUE },
      { ADI_TMR_CORE_CMD_END,             NULL  },
};
Result = adi_tmr_CoreControl(ADI_TMR_CORE_CMD_TABLE, CoreTable);

Result = adi_tmr_GPControl(ADI_TMR_GP_TIMER_0,
              ADI_TMR_GP_CMD_SET_PERIOD,      (void *)0x800000);
Result = adi_tmr_GPControl(ADI_TMR_GP_TIMER_0,
              ADI_TMR_GP_CMD_SET_WIDTH,       (void *)0x400000);
Result = adi_tmr_GPControl(ADI_TMR_GP_TIMER_0,
              ADI_TMR_GP_CMD_SET_TIMER_MODE,  (void *)0x1);

Result = adi_tmr_GPControl(ADI_TMR_GP_TIMER_1,
              ADI_TMR_GP_CMD_SET_PERIOD,      (void *)0x800000);
Result = adi_tmr_GPControl(ADI_TMR_GP_TIMER_1,
              ADI_TMR_GP_CMD_SET_WIDTH,       (void *)0x400000);
Result = adi_tmr_GPControl(ADI_TMR_GP_TIMER_1,
              ADI_TMR_GP_CMD_SET_TIMER_MODE,  (void *)0x1);

Result = adi_tmr_WatchdogControl
              (ADI_TMR_WDOG_CMD_EVENT_SELECT, (void *)0x0);
Result = adi_tmr_WatchdogControl
              (ADI_TMR_WDOG_CMD_SET_COUNT,  (void *)0x12345678);
```

Note in the above fragment that the core timer was enabled immediately after being configured and the watchdog and general-purpose timers were not enabled. Any timer can be enabled via a command table, typically the last entry in the table. For illustrative purposes, enabling the watchdog and general-purpose timers is shown separately in "Enabling and Disabling Timers".

Enabling and Disabling Timers

After the timer is configured, it can be enabled. When using a command table, the timer can be enabled as a command in the table as shown in "Configuring a Timer" on page 8-10. Typically, the command to enable the timer is the last entry in the table. Alternatively, timers can be enabled by a separate call to the appropriate control function. Further, general-purpose timers can be simultaneously enabled and disabled as a group.

The following fragment illustrates how to enable the watchdog timer and then simultaneously enable general-purpose timers 0 and 1.

```
Result = adi_tmr_WatchdogControl
             (ADI_TMR_WDOG_CMD_ENABLE_TIMER, (void *)TRUE);

Result = adi_tmr_GPGroupEnable
             (ADI_TMR_GP_TIMER_0 | ADI_TMR_GP_TIMER_1, TRUE);
```

When a timer is disabled, it can be disabled as part of a command table (though this is unlikely). More often, timers are disabled via a single control function call. As with the enabling of general-purpose timers, timers can be disabled simultaneously. The following code fragment illustrates how to disable the watchdog timer and simultaneously disable general-purpose timers 0 and 1.

```
Result = adi_tmr_WatchdogControl
            (ADI_TMR_WDOG_CMD_ENABLE_TIMER, (void *)FALSE);

Result = adi_tmr_GPGroupEnable
            (ADI_TMR_GP_TIMER_0 | ADI_TMR_GP_TIMER_1, FALSE);
```

Installing a Callback Function

While applications can install hardware interrupt service routines (ISRs) directly to process interrupts from timers (see "Interrupt Manager"), the timer service provides a simple, easy-to-use callback mechanism that provides equivalent functionality.

The following code fragment illustrates how to install a callback function. Different callback functions can be used for each timer, or a single callback function can be used for any number of timers. The fragment shows installation of a single callback function for two general-purpose timers, the core timer, and a watchdog timer. The switch statement within the callback function identifies which timer generated the callback.

```
...
Result = adi_tmr_InstallCallback
  (ADI_TMR_GP_TIMER_0, TRUE, (void *)0x00000000, NULL, Callback);
Result = adi_tmr_InstallCallback
  (ADI_TMR_GP_TIMER_1, TRUE, (void *)0x11111111, NULL, Callback);
Result = adi_tmr_InstallCallback
  (ADI_TMR_CORE_TIMER, TRUE, (void *)0x22222222, NULL, Callback);
Result = adi_tmr_InstallCallback
  (ADI_TMR_WDOG_TIMER, TRUE, (void *)0x33333333, NULL, Callback);
...
void Callback(void *ClientHandle, u32 Event, void *pArg) {
         // Event = ADI_TMR_EVENT_TIMER_EXPIRED
         switch ((u32)pArg) {
         case ADI_TMR_GP_TIMER_0:
                  // do processing when gp timer 0 expires
```

```
                // ClientHandle = 0x00000000
                break;
        case ADI_TMR_GP_TIMER_1:
                // do processing when gp timer 1 expires
                // ClientHandle = 0x11111111
                break;
        case ADI_TMR_CORE_TIMER:
                // do processing when core timer expires
                // ClientHandle = 0x22222222
                break;
        case ADI_TMR_WDOG_TIMER:
                // do processing when watchdog timer expires
                // ClientHandle = 0x33333333
        break;
        }
}
```

When the callback function is invoked, the `ClientHandle` parameter is the value given when the callback was installed, the `Event` is the `ADI_TMR_EVENT_TIMER_EXPIRED` value, and the `pArg` parameter contains the timer ID that triggered the callback. This example passes in a NULL for the deferred callback service handle, so callbacks are live.

Removing Callbacks

Should an application no longer need the callback, it can remove the callback without affecting the other timer settings. The following fragment illustrates how to remove the callbacks.

```
Result = adi_tmr_RemoveCallback(ADI_TMR_GP_TIMER_0);

Result = adi_tmr_RemoveCallback(ADI_TMR_GP_TIMER_1);

Result = adi_tmr_RemoveCallback(ADI_TMR_CORE_TIMER);

Result = adi_tmr_RemoveCallback(ADI_TMR_WDOG_TIMER);
```

The callback functions are no longer invoked and the callback functions themselves are removed from the timer service.

Termination

When the functionality provided by the timer service is no longer required, the application terminates the service. The following fragment terminates the timer service.

```
Result = adi_tmr_Terminate();
```

After termination, the timer service must be reinitialized before using any of the timer service function.

Timer Service API Reference

This section provides the timer service application programming interface (API).

The information in this section was accurate at the time this document was created. However, the include file for the timer service, `adi_tmr.h`, should be checked for current information.

Notation Conventions

The reference pages for the API functions use the following format:

Name – Name and purpose of the function

Description – Function specification

Prototype – Required header file and functional prototype

Arguments – Description of function arguments

Return Value – Description of function return values

adi_tmr_Init

Description

The `adi_tmr_Init` function initializes internal data structures of the timer service. This function should be called only once per core.

Prototype

```
ADI_TMR_RESULT adi_tmr_Init (
        void                    *pEnterCriticalArg
);
```

Arguments

`pEnterCriticalArg`	Handle to data area containing critical region data. This is passed to `adi_int_EnterCriticalRegion` where it is used internally of the module. See "Interrupt Manager" on page 2-1 for further details.

Return Value

`ADI_TMR_RESULT_SUCCESS`	Timer service was successfully initialized.
Any other value	Error has occurred. See "ADI_TMR_RESULT" on page 8-32 for a list of return codes.

adi_tmr_Open

Description

The `adi_tmr_Open` function opens a timer. The timer's registers are reset to the power-up values, status conditions are cleared, and so on. Future Blackfin devices may require this function take additional action to manipulate the hardware in some way when opening a timer.

ⓘ On multi-core Blackfin devices, each core has its own core timer. However, the watchdog timers and general-purpose timers are shared between the cores. When running the timer service on multi-core devices, ensure that multiple cores do not attempt to simultaneously use the same watchdog and general-purpose timers.

Prototype

```
void adi_tmr_Open (
        u32            TimerID
);
```

Arguments

`TimerID`	Enumerator value that uniquely identifies the timer to open

Return Value

`ADI_TMR_RESULT_SUCCESS`	Operation was successful.
Any other value	Error has occurred. See "ADI_TMR_RESULT" on page 8-32 for a list of return codes.

adi_tmr_Terminate

Description

The `adi_tmr_Terminate` function closes the timer service. Any installed callbacks are removed. Once terminated, the initialization function must be called again before using any of the timer service functions.

Prototype

```
ADI_TMR_RESULT adi_tmr_Terminate (
               void
);
```

Arguments

None

Return Value

`ADI_TMR_RESULT_SUCCESS`	Function completed successfully.
Any other value	Error has occurred. See "ADI_TMR_RESULT" on page 8-32 for a list of return codes.

adi_tmr_Close

Description

The `adi_tmr_Close` function is called when the application no longer requires the service of a timer. At present, this function does nothing but returns immediately to the caller. Future Blackfin devices may require that this function manipulate the hardware in some way when closing a timer.

Prototype

```
void adi_tmr_Close (
        u32          TimerID
);
```

Arguments

`TimerID`	Enumerator value that uniquely identifies the timer to close

Return Value

`ADI_TMR_RESULT_SUCCESS`	Operation was successful.
Any other value	Error has occurred. See "ADI_TMR_RESULT" on page 8-32 for a list of return codes.

adi_tmr_Reset

Description

The `adi_tmr_Reset` function resets the timer's registers to the power-up values. Any pending status indications (interrupts, and so on) are cleared. As this function is called from within the `adi_tmr_Open` function, there is rarely a need for an application to call this function.

Prototype

```
void adi_tmr_Reset (
        u32                TimerID
);
```

Arguments

`FlagID`	Enumerator value that uniquely identifies the timer to reset

Return Value

`ADI_TMR_RESULT_SUCCESS`	Function completed successfully.
Any other value	Error has occurred. See "ADI_TMR_RESULT" on page 8-32 for a list of return codes.

adi_tmr_CoreControl

Description

The `adi_tmr_CoreControl` function inverts the current value of the flag. If the flag is a logical 1 (driving high), this function makes the flag a logical 0 (driving low). If the flag is a logical 0 (driving low), this function makes the flag a logical 1 (driving high).

Prototype

```
void adi_tmr_CoreControl (
        ADI_TMR_CORE_CMD              Command,
        void                         *Value
);
```

Arguments

`Command`	Identifier specifying the timer parameter that is addressed. See “ADI_TMR_CORE_CMD” on page 8-33 for a list of all core timer command identifiers.
`Value`	A command-specific value that is typically the value of the parameter being set or a location into which a value read from the timer is stored

Return Value

`ADI_TMR_RESULT_SUCCESS`	Function completed successfully.
Any other value	Error has occurred. See “ADI_TMR_RESULT” on page 8-32 for a list of return codes.

adi_tmr_WatchdogControl

Description

The `adi_tmr_WatchdogControl` function configures and controls the settings of the watchdog timer.

Prototype

```
void adi_tmr_WatchdogControl (
        ADI_TMR_WDOG_CMD            Command,
        void                       *Value
);
```

Arguments

`Command`	Identifier specifying the timer parameter that is addressed. See "ADI_TMR_WDOG_CMD" on page 8-34 for a list of all watchdog timer command identifiers.
`Value`	A command-specific value that is typically the value of the parameter being set or a location into which a value read from the timer is stored

Return Value

`ADI_TMR_RESULT_SUCCESS`	Function completed successfully.
Any other value	Error has occurred. See "ADI_TMR_RESULT" on page 8-32 for a list of return codes.

adi_tmr_GPControl

Description

The `adi_tmr_GPControl` function configures and controls the settings of general-purpose timers.

Prototype

```
void adi_tmr_GPControl (
        u32                         TimerID,
        ADI_TMR_GP_CMD              Command,
        void                        *Value
);
```

Arguments

`TimerID`	Enumerator value that uniquely identifies the timer to control
`Command`	Identifier specifying the timer parameter that is addressed. See “ADI_TMR_GP_CMD” on page 8-35 for a list of all general-purpose timer command identifiers.
`Value`	A command-specific value that is typically the value of the parameter being set or a location into which a value read from the timer is stored

Return Value

`ADI_TMR_RESULT_SUCCESS`	Function completed successfully.
Any other value	Error has occurred. See “ADI_TMR_RESULT” on page 8-32 for a list of return codes.

adi_tmr_GPGroupEnable

Description

The `adi_tmr_GPGroupEnable` function simultaneously enables or disables a group of general-purpose timers. The function uses best efforts to simultaneously enable or disable the group of timers. If the underlying hardware of the specific Blackfin device allows the specified timers to be controlled simultaneously, the function takes the necessary action to simultaneously enable or disable the timers. If the underlying hardware does not allow the specified timers to be controlled simultaneously, the function uses best efforts to enable or disable the timers as quickly as possible.

Note that depending on the specific Blackfin device, when enabling the timer(s), this function may additionally configure the port muxing, based on the configuration settings for the timer.

For example, on ADSP-BF534/536/537 processors, if a general-purpose timer is configured as a PWM timer with the output pin active, when the timer is enabled, this function configures the port control logic, via the port control system service, to enable the `TMRx` pin. On ADSP-BF531/532/533 and ADSP-BF561 processors, no port control logic is necessary. No further user action with the port control service is required.

Prototype

```
void adi_tmr_GPGroupEnable (
        u32                         TimerID,
        u32                         EnableFlag
);
```

Arguments

`TimerIDs`	ORing of all general-purpose timer IDs that are simultaneously controlled
`EnableFlag`	A value of `TRUE` indicates the timers are enabled. A value of `FALSE` indicates the timers are disabled.

Return Value

`ADI_TMR_RESULT_SUCCESS`	Function completed successfully.
Any other value	Error has occurred. See "ADI_TMR_RESULT" on page 8-32 for a list of return codes.

adi_tmr_InstallCallback

Description

The adi_tmr_InstallCallback function installs a callback function that is invoked when a timer expires. Note that the function provided by the caller is a callback function, not an interrupt handler. This function does not alter timer configurations, values, or other settings in any way.

Prototype

```
void adi_tmr_InstallCallback (
        u32                         TimerID,
        u32                         WakeupFlag,
        void                        *ClientHandle,
        ADI_DCB_HANDLE              DCBHandle,
        ADI_DCB_CALLBACK_FN         ClientCallback
);
```

Arguments

`TimerID`	Enumerator value that uniquely identifies the timer to which the callback is assigned
`WakeupFlag`	If the trigger occurs, flag indicating the processor is awake from a low-power state
`ClientHandle`	Identifier defined and supplied by the client. This value is passed to the callback function.
`DCBHandle`	Either NULL if using live callbacks or the handle to the deferred callback service that is used for callbacks
`ClientCallback`	Address of the client's callback function

Return Value

`ADI_TMR_RESULT_SUCCESS`	Flag service was successfully initialized.
Any other value	Error has occurred. See "ADI_TMR_RESULT" on page 8-32 for a list of return codes.

adi_tmr_RemoveCallback

Description

The `adi_tmr_RemoveCallback` function removes the callback from the specified timer. This function does not alter timer configurations, values, or other settings in any way.

Prototype

```
void adi_tmr_RemoveCallback (
        u32                      TimerID
);
```

Arguments

`TimerID`	Enumerator value that uniquely identifies the timer whose callback is removed

Return Value

`ADI_TMR_RESULT_SUCCESS`	Function completed successfully.
Any other value	Error has occurred. See "ADI_TMR_RESULT" on page 8-32 for a list of return codes.

adi_tmr_GetPeripheralID

Description

The `adi_tmr_GetPeripheralID` function can be called to identify the peripheral ID for the specified timer. Though not normally required, this function may be useful should finer granularity of interrupt control logic than what is provided by the timer service be required. The peripheral ID value can be passed to functions in the interrupt service. Note that the core timer does not have a peripheral ID associated with it as the core timer mapping to an IVG level is fixed. Regardless, the core timer ID may still be passed to this function and the function will not return an error.

Prototype

```
void adi_tmr_GetPeripheralID (
        u32                         TimerID,
        ADI_INT_PERIPHERAL_ID       *pPeripheralID
);
```

Arguments

`TimerID`	Enumerator value that uniquely identifies the timer to control
`pPeripheralID`	Pointer to location where the peripheral ID for the specified timer is stored

Return Value

`ADI_TMR_RESULT_SUCCESS`	Function completed successfully.
Any other value	Error has occurred. See "ADI_TMR_RESULT" on page 8-32 for a list of return codes.

Public Data Types, Enumerations, and Macros

This section defines the public data structures and enumerations used by the timer service.

Always check the include file for the timer service, `adi_tmr.h`, for the most up-to-date information.

Timer IDs

The timer service provides a unique identifier for each timer. Timer IDs, which are 32-bit values, are not a simple index; instead, they are a combination of two pieces of information. Bits 27 through 31 of the timer ID are an index that enumerates each timer in the system, including general-purpose, core, and watchdog timers. Bits 0 through 26, which are used for general-purpose timers only, form a mask used by the timer service to enable and disable multiple general-purpose timers simultaneously.

Macros are provided in the `adi_tmr.h` file to create timer IDs, to access the values held in bits 0 through 26, and to access the values in bits 27 through 31. These macros are used internally by the timer service and are not typically used by applications. However, should the application need to iterate through all general-purpose timers, the timer IDs can be created by the `ADI_TMR_CREATE_GP_TIMER_ID(x)` macro, where "`x`" is in the range of 0 to (but not including) the value `ADI_TMR_GP_TIMER_COUNT`.

For example, the following code fragment illustrates how to open all general-purpose timers.

```
u32 i, TimerID;
ADI_TMR_RESULT Result;

for (i = 0; i < ADI_TMR_GP_TIMER_COUNT; i++) {
            TimerID = ADI_TMR_CREATE_GP_TIMER_ID(i);
            Result  = adi_tmr_Open(TimerID); }
```

For most functions in the timer service API, a single timer ID value is passed to the function to identify the timer being addressed. However, the `adi_tmr_GPGroupEnable()` function can take a single timer ID value or a logical ORing of multiple timer ID values as a parameter. The structure of the timer ID value allows the single passed-in parameter to identify multiple general-purpose timers to the function.

Associated Macros

These macros are defined for internal use by the timer service.

`ADI_TMR_CREATE_GP_TIMER_ID`	Creates a timer ID given a general-purpose timer index.
`ADI_TMR_CREATE_CORE_TIMER_ID`	Creates a timer ID given a core timer index.
`ADI_TMR_CREATE_WDOG_TIMER_ID`	Creates a timer ID given a watchdog timer index.
`ADI_TMR_GET_TIMER_INDEX`	Gets the timer index given a timer ID.
`ADI_TMR_GET_GP_TIMER_MASK`	Gets the mask for a general-purpose timer(s) given a single timer ID or logical ORing of multiple timer IDs.

ADI_TMR_RESULT

Each API function of the timer service returns an ADI_TMR_RESULT enumeration as a return code. Similar to all system services, generic success is defined as 0 and generic failure is defined as 1. This allows the calling function to quickly evaluate the return code for a zero or nonzero value.

All detailed result codes for the timer service begin with the value ADI_TMR_ENUMERATION_START, for easy identification.

Result Code	Description
ADI_TMR_RESULT_SUCCESS	Function executed correctly.
ADI_TMR_RESULT_FAILED	Function execution not completed.
ADI_TMR_RESULT_NOT_SUPPORTED	Operation is not supported.
ADI_TMR_RESULT_BAD_TIMER_ID	(0x70002) TimerID value is invalid.
ADI_TMR_RESULT_BAD_TIMER_IDS	(0x70003) Timer ID values are invalid.
ADI_TMR_RESULT_BAD_TIMER_TYPE	Operation is not appropriate to the timer ID supplied.
ADI_TMR_RESULT_BAD_COMMAND	Invalid command.
ADI_FLAG_RESULT_INTERRUPT_MANAGER_ERROR	Interrupt manager service returned an error.
ADI_TMR_RESULT_CALLBACK_ALREADY_INSTALLED	Callback is already installed on the given timer.

ADI_TMR_EVENT

The ADI_TMR_EVENT enumeration defines the type of callback event that occurred. There is only one value, ADI_TMR_EVENT_TIMER_EXPIRED. This enumeration type is different from all other event types for system services—a single callback function can be used for any service, regardless of the events it processes. Event codes for the timer service begin with the value ADI_TMR_ENUMERATION_START for easy identification.

Event Code	Description
ADI_TMR_EVENT_TIMER_EXPIRED	Given timer expired.

ADI_TMR_CORE_CMD

Table 8-1 lists the commands that can be executed for the core timer. These command IDs are passed as a parameter to the adi_tmr_CoreCommand() function. In addition to the command ID, the Value parameter (a void * type) is also passed to the function. The meaning of the Value parameter depends on the command ID being passed. Table 8-1 also describes the Value parameter for each command ID.

Table 8-1. Commands Executed for Core Timer

Command ID	Value	Description
ADI_TMR_CORE_CMD_TABLE	ADI_TMR_CORE_CMD_VALUE_PAIR *	Start of command table
ADI_TMR_CORE_CMD_END	Ignored	End of command table
ADI_TMR_CORE_CMD_PAIR	ADI_TMR_CORE_CMD_VALUE_PAIR *	Command pair
ADI_TMR_CORE_CMD_SET_ACTIVE_MODE	TRUE – active mode FALSE – low power	Sets active or low power mode of timer.

Table 8-1. Commands Executed for Core Timer (Cont'd)

Command ID	Value	Description
ADI_TMR_CORE_CMD_ENABLE_TIMER	TRUE – enabled FALSE – disabled	Enables or disables the timer.
ADI_TMR_CORE_CMD_SET_AUTO_RELOAD	TRUE – auto reload FALSE – no reload	Enables or disables automatic reloading of timer.
ADI_TMR_CORE_CMD_HAS_INTERRUPT_OCCURRED	u32 * TRUE – enabled FALSE – disabled	Indicates if the timer interrupt has occurred.
ADI_TMR_CORE_CMD_RESET_INTERRUPT_OCCURRED	Ignored	Clears the indication that the timer interrupt has occurred.
ADI_TMR_CORE_CMD_SET_COUNT	u32	Sets the count value for the timer.
ADI_TMR_CORE_CMD_SET_PERIOD	u32	Sets the period value for the timer.
ADI_TMR_CORE_CMD_SET_SCALE	u32	Sets the scale value for the timer.

ADI_TMR_WDOG_CMD

Table 8-2 lists the commands that can be executed for the watchdog timer. These command IDs are passed as a parameter to the `adi_tmr_WatchdogCommand()` function. In addition to the command ID, the `Value` parameter (a `void *` type) is also passed to the function. The meaning of the `Value` parameter depends on the command ID being passed. Table 8-2 also describes the `Value` parameter for each command ID.

Table 8-2. Commands Executed for Watchdog Timer

Command ID	Value	Description
ADI_TMR_WDOG_CMD_TABLE	ADI_TMR_WDOG_CMD_VALUE_PAIR *	Start of command table
ADI_TMR_WDOG_CMD_END	Ignored	End of command table
ADI_TMR_WDOG_CMD_PAIR	ADI_TMR_WDOG_CMD_VALUE_PAIR *	Command pair
ADI_TMR_WDOG_CMD_EVENT_SELECT	0 – reset 1 – NMI 2 – GP interrupt 3 – no event	Sets the event type that occurs upon expiration of the watchdog timer.
ADI_TMR_WDOG_CMD_ENABLE_TIMER	TRUE – enabled FALSE – disabled	Enables or disables the timer.
ADI_TMR_WDOG_CMD_HAS_EXPIRED	u32 * TRUE – enabled FALSE – disabled	Indicates if the timer has expired.
ADI_TMR_WDOG_CMD_RESET_EXPIRED	Ignored	Clears the indication that the timer has expired.
ADI_TMR_WDOG_CMD_GET_STATUS	u32 *	Stores the current count value into the specified location.
ADI_TMR_WDOG_CMD_SET_COUNT	u32	Sets the current count value.
ADI_TMR_WDOG_CMD_RELOAD_STATUS	u32 *	Reloads the status register from the count register.

ADI_TMR_GP_CMD

Table 8-3 lists the commands that can be executed for general-purpose timers. These command IDs are passed as a parameter to the `adi_tmr_GPCommand()` function. In addition to the command ID, the

Value parameter (a void * type) is also passed to the function. The meaning of the Value parameter depends on the command ID being passed. Table 8-3 also describes the Value parameter for each command ID.

Table 8-3. Commands Executed for General-Purpose Timers

Command ID	Value	Description
ADI_TMR_GP_CMD_TABLE	ADI_TMR_GP_CMD_VALUE_PAIR *	Start of command table
ADI_TMR_GP_CMD_END	Ignored	End of command table
ADI_TMR_GP_CMD_PAIR	ADI_TMR_GP_CMD_VALUE_PAIR *	Command pair
ADI_TMR_GP_CMD_SET_PERIOD	u32	Sets the period value for the timer.
ADI_TMR_GP_CMD_SET_WIDTH	u32	Sets the width value for the timer.
ADI_TMR_GP_CMD_GET_WIDTH	u32 *	Stores the current width value for the timer in the specified location.
ADI_TMR_GP_CMD_GET_COUNTER	u32 *	Stores the counter value for the timer in the specified location.
ADI_TMR_GP_CMD_SET_TIMER_MODE	0 – reserved 1 – PWM 2 – WDTH_CAP 3 – EXT_CLK	Sets the operating mode of the timer.
ADI_TMR_GP_CMD_SET_PULSE_HI	TRUE – positive action pulse FALSE – negative action pulse	Sets the pulse action of the timer.
ADI_TMR_GP_CMD_SET_COUNT_METHOD	TRUE – count to end of period FALSE – count to end of width	Sets the count method.

Table 8-3. Commands Executed for General-Purpose Timers (Cont'd)

Command ID	Value	Description
ADI_TMR_GP_CMD_SET_INTERRUPT_ENABLE	TRUE – enables interrupt generation FALSE – disables interrupt generation	Enables or disables interrupt generation for the timer.
ADI_TMR_GP_CMD_SET_INPUT_SELECT	TRUE – UART_RX or PPI_CLK FALSE – TMRx or PF1	Selects the timer input.
ADI_TMR_GP_CMD_SET_OUTPUT_PAD_DISABLE	TRUE – output pad disabled FALSE – output pad enabled	Enables or disables the TMRx pin.
ADI_TMR_GP_CMD_SET_CLOCK_SELECT	TRUE – PWM_CLK FALSE – SCLK	Selects the input clock for the timer.
ADI_TMR_GP_CMD_SET_TOGGLE_HI	TRUE – PULSE_HI alternated each period FALSE – use programmed state	Sets the toggle mode.
ADI_TMR_GP_CMD_RUN_DURING_EMULATION	TRUE – run during emulation FALSE – do not run during emulation	Enables or disables the timer when the device is servicing emulator interrupts.
ADI_TMR_GP_CMD_GET_ERROR_TYPE	u32 * 0 – no error 1 – counter overflow 2 – period register error 3 – width register error	Stores the error type in the specified location.
ADI_TMR_GP_CMD_IS_INTERRUPT_ASSERTED	u32 * TRUE – asserted FALSE – not asserted	Stores the interrupt assertion status in the specified location.
ADI_TMR_GP_CMD_CLEAR_INTERRUPT	Ignored	Clears the timer's interrupt.

Table 8-3. Commands Executed for General-Purpose Timers (Cont'd)

Command ID	Value	Description
ADI_TMR_GP_CMD_IS_ERROR	u32 * TRUE – error FALSE – no error	Stores the error status in the specified location.
ADI_TMR_GP_CMD_CLEAR_ERROR	Ignored	Clears the error status of the timer.
ADI_TMR_GP_CMD_IS_SLAVE_ENABLED	u32 * TRUE – enabled FALSE – disabled	Stores the slave enable status in the specified location.
ADI_TMR_GP_CMD_IMMEDIATE_HALT	Ignored	Immediately stops timer in PWM mode.
ADI_TMR_GP_CMD_ENABLE_TIMER	TRUE – enabled FALSE – disabled	Enables or disables the timer.
ADI_TMR_GP_CMD_SET_ENABLE_DELAY	u32	Number of SCLK cycles to delay between the enabling of each timer

9 PORT CONTROL SERVICE

This chapter describes the port control manager service.

This service is available for ADSP-BF534, ADSP-BF536, and ADSP-BF537 Blackfin processors only.

This chapter contains the following sections:

Introduction

The port control manager service, within the system services library, provides the client applications' developer with a means of assigning the programmable flag pins to various functions. For instance, the flag pins required for SPORT0 usage can be set up with a single call to the adi_ports_EnableSPORT function.

Where necessary, the memory-mapped registers for the appropriate peripherals are queried to determine behavior. For example, the port control manager can interrogate the PPI_CONTROL register to determine whether two internal frame syncs are required. However, it is the responsibility of the client program to configure the PPI control registers prior to enabling the required flag pins. This is the usual practice within the device driver model, where port control and the setting of flag values are done at the point of enabling dataflow.

The port control manager is applicable only to processors that support port control, which is currently available only on the ADSP-BF534, ADSP-BF536, and ADSP-BF537 Blackfin processors.

The port control manager uses an unambiguous naming convention to safeguard against conflicts with other software libraries provided by Analog Devices or elsewhere. All enumeration values and typedef statements use the ADI_PORTS_ prefix, and functions and global variables use the lowercase adi_ports_ equivalent.

Using the Port Control Manager

To demonstrate the use of the port control manager, an example is presented that configures the PPI for use with two internal frame syncs.

The port control manager is initialized as follows.

```
adi_ports_Init(     // Initialize Port Control Manager

          NULL      // No special data area for critical
                    // regions required

);
```

To enable the flag pins for the required PPI use, the `adi_ports_EnablePPI` function is called with an array of directives that determine how to configure the register.

```
// Configure the PPI_CONTROL register
ADI_PPI_CONTROL_REG ppi_control;
ppi_control.port_en  = 0;    // Disable until ready
ppi_control.port_dir = 0;    // Receive mode
ppi_control.xfr_type = 3;    // Non ITU-R 656 mode
ppi_control.port_cfg = 1;    // two or three internal frame syncs
ppi_control.dlen     = 7;    // 16 Bits data length
ppi_control.polc     = 0;    // Do not invert PPI_CLK
ppi_control.pols     = 0;    // Do not invert PPI_FS1 & PPI_FS2

// set PPI_COUNT to 1 to sample 2 16-bit words.
u16 ppi_count = 1;
u16 ppi_frame = 1;

ADI_DEV_CMD_VALUE_PAIR PPI_config[] = {
{ ADI_PPI_CMD_SET_CONTROL_REG, (void*)(*(u16*)&ppi_control)   },
{ ADI_PPI_CMD_SET_TRANSFER_COUNT_REG, (void*)(*(u16*)&ppi_count)
},
```

```
{ ADI_PPI_CMD_SET_LINES_PER_FRAME_REG,
(void*)(*(u16*)&ppi_frame)},
{ ADI_DEV_CMD_END, 0 }
};

// Program PPI peripheral
adi_dev_Control(
        ppiHandle,
        ADI_DEV_CMD_TABLE,
        (void*)PPI_config );

// other configuration code for PPI, eg Timers, etc  :
// The following would be elsewhere in the client code

// Configure pins for PPI use
u32 ppi_config[] = { ADI_PORTS_DIR_PPI_BASE };
adi_ports_EnablePPI(
        ppi_config,                     // Array of directives
        sizeof(ppi_config)/sizeof(u32), // Number of directives
        1                               // Enable
);

// Enable Data Flow
adi_dev_Control(ppiHandle, ADI_DEV_CMD_SET_DATAFLOW, 1);
```

Finally, when the port control manager is no longer required, the service is terminated with a call to a`di_ports_Terminate3`:

```
adi_ports_Terminate();
```

Port Control Manager API Reference

This section provides the port control manager service application program interface (API).

Notation Conventions

The reference pages for the API functions use the following format:

Name – Name and purpose of the function

Description – Function specification

Prototype – Required header file and functional prototype

Arguments – Description of function arguments

Return Value – Description of function return values

adi_ports_Init

Description

The adi_ports_Init function initializes the port control manager.

Prototype

```
ADI_PORTS_RESULT adi_ports_Init (
        void                        *pEnterCriticalArg
);
```

Arguments

pEnterCriticalArg	Handle to data area containing critical region data. This is passed to adi_int_EnterCriticalRegion where it is used internally of the module. See "Interrupt Manager" on page 2-1 for further details.

Return Value

ADI_PORTS_RESULT_SUCCESS	Port control manager was successfully initialized.

adi_ports_Terminate

Description

The adi_ports_Terminate function terminates the port control manager.

Prototype

```
ADI_PORTS_RESULT adi_ports_Terminate (
                 void
);
```

Arguments

None

Return Value

ADI_PORTS_RESULT_SUCCESS	Function completed successfully.

adi_ports_EnablePPI

Description

The adi_ports_EnablePPI function configures the port control registers to enable the use of the required PPI channel.

Prototype

```
adi_ports_EnablePPI (
        u32                     *Directives,
        u32                     nDirectives,
        u32                     Enable
);
```

Arguments

Directives	Address of an array of directives describing how the to configure the PPI flags. See “Directive Enumeration Values” on page 9-17.
nDirectives	Number of entries in Directives array
Enable	Flag determining whether the functionality is enabled (1) or disabled (0)

Return Value

In debug mode, this routine returns one of the following result codes. Otherwise, ADI_PORTS_RESULT_SUCCESS is always returned.

ADI_PORTS_RESULT_SUCCESS	Function completed successfully.
ADI_PORTS_RESULT_NULL_ARRAY	Address of the Directives array is NULL.
ADI_PORTS_RESULT_BAD_DIRECTIVE	Invalid directive value has been passed.

adi_ports_EnableSPI

Description

The adi_ports_EnableSPI function configures the port control registers to enable the use of the required SPI channel.

Prototype

```
adi_ports_EnableSPI (
        u32                     *Directives,
        u32                     nDirectives,
        u32                     Enable
);
```

Arguments

Directives	Address of an array of directives describing how to configure the SPI flags. See "Directive Enumeration Values" on page 9-17.
nDirectives	Number of entries in Directives array
Enable	Flag determining whether the functionality is enabled (1) or disabled (0)

Return Value

In debug mode, this routine returns one of the following result codes. Otherwise, ADI_PORTS_RESULT_SUCCESS is always returned.

ADI_PORTS_RESULT_SUCCESS	Function completed successfully.
ADI_PORTS_RESULT_NULL_ARRAY	Address of the Directives array is NULL.
ADI_PORTS_RESULT_BAD_DIRECTIVE	Invalid directive value has been passed.

adi_ports_EnableSPORT

Description

The adi_ports_EnableSPORT function configures the port control registers to enable the use of the required SPORT channel.

Prototype

```
adi_ports_EnableSPORT (
        u32                     *Directives,
        u32                     nDirectives,
        u32                     Enable
);
```

Arguments

Directives	Address of an array of directives describing how the to configure the SPORT flags. See "Directive Enumeration Values" on page 9-17.
nDirectives	Number of entries in Directives array
Enable	Flag determining whether the functionality is enabled (1) or disabled (0)

Return Value

In debug mode, this routine returns one of the following result codes. Otherwise, ADI_PORTS_RESULT_SUCCESS is always returned.

ADI_PORTS_RESULT_SUCCESS	Function completed successfully.
ADI_PORTS_RESULT_NULL_ARRAY	Address of the Directives array is NULL.
ADI_PORTS_RESULT_BAD_DIRECTIVE	Invalid directive value has been passed.

adi_ports_EnableUART

Description

The adi_ports_EnableUART function configures the port control registers to enable the use of the required UART channel.

Prototype

```
adi_ports_EnableUART (
        u32                     *Directives,
        u32                     nDirectives,
        u32                     Enable
);
```

Arguments

Directives	Address of an array of directives describing how the to configure the UART flags. See "Directive Enumeration Values" on page 9-17.
nDirectives	Number of entries in Directives array
Enable	Flag determining whether the functionality is enabled (1) or disabled (0)

Return Value

In debug mode, this routine returns one of the following result codes. Otherwise, ADI_PORTS_RESULT_SUCCESS is always returned.

ADI_PORTS_RESULT_SUCCESS	Function completed successfully.
ADI_PORTS_RESULT_NULL_ARRAY	Address of the Directives array is NULL.
ADI_PORTS_RESULT_BAD_DIRECTIVE	Invalid directive value has been passed.

adi_ports_EnableCAN

Description

The adi_ports_EnableCAN function configures the port control registers to enable the use of the required CAN channel.

Prototype

```
adi_ports_EnableCAN (
        u32                     *Directives,
        u32                     nDirectives,
        u32                     Enable
);
```

Arguments

Directives	Address of an array of directives describing how the to configure the CAN flags. See “Directive Enumeration Values” on page 9-17.
nDirectives	Number of entries in Directives array
Enable	Flag determining whether the functionality is enabled (1) or disabled (0)

Return Value

In debug mode, this routine returns one of the following result codes. Otherwise, ADI_PORTS_RESULT_SUCCESS is always returned.

ADI_PORTS_RESULT_SUCCESS	Function completed successfully.
ADI_PORTS_RESULT_NULL_ARRAY	Address of the Directives array is NULL.
ADI_PORTS_RESULT_BAD_DIRECTIVE	Invalid directive value has been passed.

adi_ports_EnableTimer

Description

The `adi_ports_EnableTimer` function configures the port control registers to enable the appropriate flag pins for the output of general-purpose (GP) timer clock signals, the timer clock input (used mainly for PPI clock), alternate timer clock inputs[1], and for bit rate detection on CAN and UART inputs.[2]

Any number of pins as required can be assigned in the one call to `adi_ports_EnableTimer`.

Prototype

```
adi_ports_EnableTimer (
        u32                     *Directives,
        u32                     nDirectives,
        u32                     Enable
);
```

Arguments

`Directives`	Address of an array of directives describing the timers for which the flags are configured. See "Directive Enumeration Values" on page 9-17.
`nDirectives`	Number of entries in `Directives` array
`Enable`	Flag determining whether the functionality is enabled (1) or disabled (0)

[1] Alternatively, the `TACLKx` flag pins can provide the clock signal to the general-purpose timers in `PWM_OUT` mode. For details, see "Timer Service" on page 8-1.

[2] Timers must be configured for `WDTH_CAP` mode. For details, see "Timer Service" on page 8-1.

Return Value

In debug mode, this routine returns one of the following result codes. Otherwise, ADI_PORTS_RESULT_SUCCESS is always returned.

ADI_PORTS_RESULT_SUCCESS	Function completed successfully.
ADI_PORTS_RESULT_NULL_ARRAY	Address of the Directives array is NULL.
ADI_PORTS_RESULT_BAD_DIRECTIVE	Invalid directive value has been passed.
ADI_PORTS_RESULT_PIN_ALREADY_IN_USE	One of the required pins has already been assigned a different functionality.

adi_ports_EnableGPIO

Description

The `adi_ports_EnableGPIO()` function configures the port control registers to enable any number of flag pins for GPIO use.

By default, GPIO use is enabled upon system reset.

Prototype

```
adi_ports_EnableGPIO (
        u32                     *Directives,
        u32                     nDirectives,
        u32                     Enable
);
```

Arguments

`Directives`	Address of an array of directives describing which pins are configured for GPIO use. See "Directive Enumeration Values" on page 9-17)\.
`nDirectives`	Number of entries in `Directives` array
`Enable`	Flag determining whether the functionality is enabled (1) or disabled (0)

Return Value

In debug mode, this routine returns one of the following result codes. Otherwise, `ADI_PORTS_RESULT_SUCCESS` is always returned.

`ADI_PORTS_RESULT_SUCCESS`	Function completed successfully.
`ADI_PORTS_RESULT_NULL_ARRAY`	Address of the `Directives` array is NULL.
`ADI_PORTS_RESULT_BAD_DIRECTIVE`	Invalid directive value has been passed.
`ADI_PORTS_RESULT_PIN_ALREADY_IN_USE`	One of the required pins has already been assigned a different functionality.

Public Data Types, Enumerations, and Macros

This section defines public data structures and enumerations used by the port control manager service.

Always check the include file for the port control manager, `adi_ports.h`, for the most up-to-date information.

ADI_PORTS_RESULT

These values have been defined in the context of the relevant function call. The complete list is found in Table 9-1.

Table 9-1. ADI_PORTS_RESULT Values

Result Code	Numerical Value	Description
`ADI_PORTS_RESULT_SUCCESS`	0	Function executed correctly.
`ADI_PORTS_RESULT_FAILED`	1	Function execution not completed.
`ADI_PORTS_RESULT_BAD_ DIRECTIVE`	0x90001	Invalid directive value has been passed.
`ADI_PORTS_RESULT_NULL_ARRAY`	0x90002	Address of the `Directives` array is NULL.

Directive Enumeration Values

The `Directives` are describe by an anonymous enumeration type as shown in Table 9-2.

Table 9-2. Port Control Manager Enumeration Types

Enumeration Type	Description
PPI Operation	
`ADI_PORTS_DIR_PPI_BASE`	Enables flag pins for basic PPI operation.
`ADI_PORTS_DIR_PPI_FS3`	Enables flag pin for 3rd PPI framesync.
SPI Operation	
`ADI_PORTS_DIR_SPI_BASE`	Enables flag pins for basic PPI operation.
`ADI_PORTS_DIR_SPI_SLAVE_SELECT_1`	Enables flag pins for SPI SlaveSelect 1.
`ADI_PORTS_DIR_SPI_SLAVE_SELECT_2`	Enables flag pins for SPI SlaveSelect 2.
`ADI_PORTS_DIR_SPI_SLAVE_SELECT_3`	Enables flag pins for SPI SlaveSelect 3.
`ADI_PORTS_DIR_SPI_SLAVE_SELECT_4`	Enables flag pins for SPI SlaveSelect 4.
`ADI_PORTS_DIR_SPI_SLAVE_SELECT_5`	Enables flag pins for SPI SlaveSelect 5.
`ADI_PORTS_DIR_SPI_SLAVE_SELECT_6`	Enables flag pins for SPI SlaveSelect 6.
`ADI_PORTS_DIR_SPI_SLAVE_SELECT_7`	Enables flag pins for SPI SlaveSelect 7.
SPORT Operation	
`ADI_PORTS_DIR_SPORT0_BASE_RX`	Enables flag pins for basic SPORT receive operation.
`ADI_PORTS_DIR_SPORT0_BASE_TX`	Enables flag pins for basic SPORT transmit operation.
`ADI_PORTS_DIR_SPORT0_RXSE`	Enables flag pin for SPORT secondary data receive.
`ADI_PORTS_DIR_SPORT0_TXSE`	Enables flag pin for SPORT secondary data transmit.
`ADI_PORTS_DIR_SPORT1_BASE_RX`	Enables flag pins for basic SPORT receive operation.
`ADI_PORTS_DIR_SPORT1_BASE_TX`	Enables flag pins for basic SPORT transmit operation.
`ADI_PORTS_DIR_SPORT1_RXSE`	Enables flag pin for SPORT secondary data receive.
`ADI_PORTS_DIR_SPORT1_TXSE`	Enables flag pin for SPORT secondary data transmit.

Table 9-2. Port Control Manager Enumeration Types (Cont'd)

Enumeration Type	Description
UART Operation	
ADI_PORTS_DIR_UART0_RX	Enables flag pins for basic UART receive operation.
ADI_PORTS_DIR_UART0_TX	Enables flag pins for basic UART transmit operation.
ADI_PORTS_DIR_UART1_RX	Enables flag pins for basic UART receive operation.
ADI_PORTS_DIR_UART1_TX	Enables flag pins for basic UART transmit operation.
CAN Operation	
ADI_PORTS_DIR_CAN_RX	Enables flag pins for basic CAN receive operation.
ADI_PORTS_DIR_CAN_TX	Enables flag pins for basic CAN transmit operation.
Timer Operation	
ADI_PORTS_DIR_TMR_CLK	Enables flag pin for Timer Input Clock use.
ADI_PORTS_DIR_TMR_0	Enables flag pin for GP Timer 0 use.
ADI_PORTS_DIR_TMR_1	Enables flag pin for GP Timer 1 use.
ADI_PORTS_DIR_TMR_2	Enables flag pin for GP Timer 2 use.
ADI_PORTS_DIR_TMR_3	Enables flag pin for GP Timer 3 use.
ADI_PORTS_DIR_TMR_4	Enables flag pin for GP Timer 4 use.
ADI_PORTS_DIR_TMR_5	Enables flag pin for GP Timer 5 use.
ADI_PORTS_DIR_TMR_6	Enables flag pin for GP Timer 6 use.
ADI_PORTS_DIR_TMR_7	Enables flag pin for GP Timer 7 use.
GPIO Operation	
ADI_PORTS_DIR_GPIO_PF0	Enables PF0 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PF1	Enables PF1 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PF2	Enables PF2 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PF3	Enables PF3 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PF4	Enables PF4 pin for GPIO use.

Table 9-2. Port Control Manager Enumeration Types (Cont'd)

Enumeration Type	Description
ADI_PORTS_DIR_GPIO_PF5	Enables PF5 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PF6	Enables PF6 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PF7	Enables PF7 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PF8	Enables PF8 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PF9	Enables PF9 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PF10	Enables PF10 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PF11	Enables PF11 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PF12	Enables PF12 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PF13	Enables PF13 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PF14	Enables PF14 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PF15	Enables PF15 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PG0	Enables PG0 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PG1	Enables PG1 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PG2	Enables PG2 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PG3	Enables PG3 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PG4	Enables PG4 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PG5	Enables PG5 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PG6	Enables PG6 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PG7	Enables PG7 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PG8	Enables PG8 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PG9	Enables PG9 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PG10	Enables PG10 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PG11	Enables PG11 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PG12	Enables PG12 pin for GPIO use.

Table 9-2. Port Control Manager Enumeration Types (Cont'd)

Enumeration Type	Description
ADI_PORTS_DIR_GPIO_PG13	Enables PG13 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PG14	Enables PG14 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PG15	Enables PG15 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PH0	Enables PH0 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PH1	Enables PH1 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PH2	Enables PH2 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PH3	Enables PH3 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PH4	Enables PH4 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PH5	Enables PH5 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PH6	Enables PH6 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PH7	Enables PH7 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PH8	Enables PH8 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PH9	Enables PH9 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PH10	Enables PH10 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PH11	Enables PH11 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PH12	Enables PH12 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PH13	Enables PH13 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PH14	Enables PH14 pin for GPIO use.
ADI_PORTS_DIR_GPIO_PH15	Enables PH15 pin for GPIO use.

10 DEVICE DRIVER MANAGER

This chapter describes the Analog Devices device driver model. Use the device driver model to control devices, both internal and external, to Analog Devices processors. This includes on-board peripherals, such as SPORTs and parallel peripheral interface (PPI), and off-chip connected devices such as codecs and converters.

This chapter contains the following sections:

- "Device Driver Model Overview" on page 10-3
  Provides a general overview of the functionality provided by the device driver model and a brief description of the overall device driver architecture.

- "Using the Device Manager" on page 10-6
  Describes how applications invoke and interact with the device driver model including an explanation of the different dataflow methods supported in the model.

- "Device Manager Design" on page 10-30
  Describes the device driver manager API and inner workings of the device driver manager. Specifically, this section describes how the device driver manager operates and what it does in response to API calls and interaction with physical drivers.

- "Physical Driver Design" on page 10-45
  Explains how physical drivers can be written to comply with the model and describes how physical device drivers interact with the device driver manager.

- "Device Manager API Reference" on page 10-57
  Describes the API functions of the device driver manager.

- "Device Manager Public Data Types and Enumerations" on page 10-66
  Provides tables for all the device manager data structures and enumerations.

- "Physical Driver API Reference" on page 10-83
  Describes the API used between the device driver manager and each physical driver.

- "Examples" on page 10-90
  Provides PPI driver and UART driver code examples.

For detailed information regarding the use of specific device drivers, including command IDs, event codes, return codes, example code, and so on, refer to the individual device driver documents located in the `Blackfin/docs/drivers` directory of your VisualDSP++ installation.

The interface from the application to the device driver provides a consistent, simple, and familiar API to most programmers. While there is always some level of overhead involved in any standardization-type effort, the benefits of a unified model far outweigh any minor inefficiencies. The model makes it relatively simple to create a new device driver, allows applications to largely insulate themselves from any device driver specifics, and allows the device drivers to maximize use of any hardware features.

It is not expected that this model will be universally acceptable. There will be devices that do not fit into the model, or applications that want to work with a device in some unique manner, and so on. The objective of this model is to provide a simple, efficient framework that works for the majority of applications.

All sources to the device driver model are included in the various distributions of the model. While it is not expected that the sources will need to be modified or tailored to any specific application, they are provided in order for the user to fully understand how the code works.

The terms *device manager* and *physical driver* refer to the respective software components. The term *device driver* refers to the combination of the device driver manager (called device manager in this book) and physical driver.

Device Driver Model Overview

The device driver model is built using a hierarchical approach. Figure 10-1 illustrates the various components of the system design.

The components shown in the figure are:

- **Application** – Though typically the user's application, this block can be any software component that can be thought of as a client of the device manager. Note that the client does not have to be a single functional block. The device manager can support any number of clients. For example, a client may be a single-user application or the client may be any number of tasks in RTOS-controlled systems.
- **RTOS** – Some systems use the services of a real-time operating system (RTOS). The device driver model is not tailored to a particular RTOS, nor does it require the presence of an RTOS. The device driver model does not require any functionality or services from an RTOS. Some real-time operating systems require that applications go through the RTOS in order to access device drivers. In these systems, the RTOS is simply viewed as a client to the device manager.

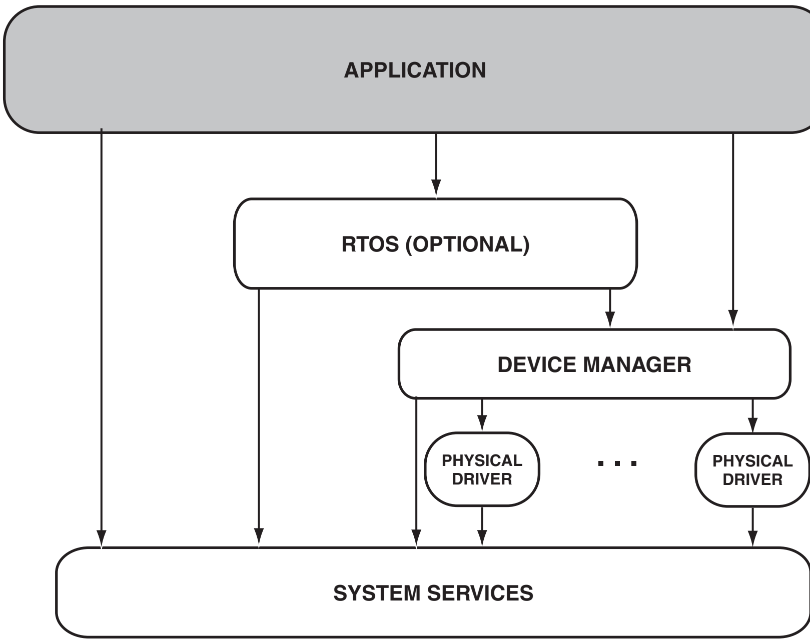


Figure 10-1. System Design and Hierarchy

- **Device Manager –** The device manager provides the single point of access into the device driver model. The device manager provides the API into the model. All interaction between the client and device drivers occurs through the device manager. In addition to providing the API, the device manager ensures that the client makes calls into the API in the proper sequence, performs synchronization services as needed, and controls all peripheral DMA (via the system services DMA manager) for devices that are supported by peripheral DMA.

- **Physical Drivers –** Physical device drivers provide the functionality necessary to control a physical device (for example, any configurations register setting, device parameter setting, and so on). Physical drivers are responsible for hooking into the error interrupts for their device and processing them accordingly. If a device is not supported by peripheral DMA, the physical driver must provide the mechanism, a programmed I/O or the like, to move data through the device.
- **System Services –** The device driver components rely heavily on the functionality provided by the system services. For example, the device manager relies on the interrupt manager and if required, the DMA manager and deferred callback services. The functionality provided by the system services is also available to physical drivers to use. For example, a UART driver may need to know the `SCLK` frequency in order to configure the UART to operate at a specific baud rate. Through the power management service, the UART physical driver can ascertain the current `SCLK` frequency.

Both the device driver model and system services are designed as portable software components. They are mainly written in C, with some assembly code in critical sections. As such, software that interacts with the device driver model and system services must adhere to the C run-time model, calling conventions, passing parameters, and so on. Applications and physical drivers can be written in C or assembly. Wherever possible, there are no dependencies on the code generation toolchain. System include files are not required nor are the services of the toolchain's run-time libraries. The device driver model and system services can be built and run under any of the known code generation toolchains.

No dynamic memory allocation is used in the device driver model or system services. Static memory allocation has been kept to a minimum, and the vast majority of all data memory required is passed into the device driver model and system services by the client or application. This allows the user to determine the amount of memory allocated (and from which memory space) and the device driver model and system services to use.

Using the Device Manager

The device manager provides the access point into the device driver model. The device manager presents the device manager API to the application or client.

Device Manager Overview

The device manager API consists of these functions:

- `adi_dev_Init` – Provides data and initializes the device manager
- `adi_dev_Terminate` - Frees data and closes the device manager
- `adi_dev_Open` – Opens the device for use
- `adi_dev_Control` – Sets and detects device specific parameters
- `adi_dev_Read` – Reads data from a device or queues reception buffers to a device
- `adi_dev_Write` – Writes data to a device or queues transmission buffers to a device
- `adi_pdd_Close` – Closes the device

In addition to the API functions into the device manager, the application provides the device manager with a callback function. Often, the device manager or physical driver encounters an event that needs to be passed to the user application. The event may be an expected event, such as an indication that the device driver has completed processing a buffer, or it may be an unexpected event, such as an error condition generated by the device. All events are reported back to the application via a callback function. A *callback function* is simply a function within the user application that the device manager calls to pass along event information.

Theory of Operation

The device driver model is built around the concept that a device is used to move data into and/or out of the system. In most systems, a device is used to move data into the system (where the data is processed) and another device that moves the processed data out of the system. Often, multiple devices run simultaneously in the system. The device manager provides a simple and straightforward interface, regardless of how many devices are active at any one point in time and the underlying implementation details of each device.

Data

Data that is moved into or out of the device is encapsulated in a buffer. The device manager API defines three different types of buffers:

- One-dimensional buffers called `ADI_DEV_1D_BUFFER`
- Two-dimensional buffers called `ADI_DEV_2D_BUFFER`
- Circular (autobuffer type) buffers called `ADI_DEV_CIRCULAR_BUFFER`

Because the physical movement of data uses valuable computing resources and has very little benefit, only the pointers to buffers are typically passed between components. The device manager API defines the `ADI_DEV_BUFFER` data type as a pointer to a union of a one-dimensional buffer, a two-dimensional buffer, and a circular buffer. Though each of these types of buffers is processed differently, where no significant difference in processing exists, they are collectively referred to as simply a *buffer* within this text.

In general, applications provide buffers through the device manager API, where the buffers are processed and then made available again to the application. The `adi_dev_Read` function provides the device with buffers, which are filled with data that is inbound from the device. The `adi_dev_Write` function provides the device with buffers that contain data sent out through the device.

Buffers are processed in the order in which they are received. Buffers provided to a given device need not be a uniform size; each individual buffer can be any arbitrary size. Further, both one-dimensional and two-dimensional buffers can be provided to a single device. Circular buffers are more complex (see "Providing Buffers to a Device" on page 10-15).

Initializing the Device Manager

Before using a device, the application or client must first initialize the device manager. The client initializes the device manager by calling the `adi_dev_Init` function and passing a portion of memory to it that the device manager can use for processing. The client decides how much memory (and from which memory space) to provide the device manager; the more memory provided, the more physical devices can be simultaneously opened.

The device manager requires a contiguous block of memory that can be thought of two parts—one part is base memory required for the device manager to instantiate itself, and the other part is memory that is required to support n number of simultaneously opened device drivers. Macros (`ADI_DEV_BASE_MEMORY` and `ADI_DEV_DEVICE_MEMORY`) are provided to define the amount of memory (in bytes) required for the base memory and incremental device driver memory, respectively.

For example, if the client wants to initialize the device manager and would have at most four device drivers open simultaneously at any point in time, the amount of memory required is:

```
ADI_DEV_BASE_MEMORY+(ADI_DEV_DEVICE_MEMORY*4)).
```

When called, the initialization function, `adi_dev_Init()`, initializes the memory that was passed in. Like all functions within the device manager, the initialization function returns a return code that indicates success or the specific error that occurred during the function call. All device manager API functions return the `ADI_DEV_RESULT_SUCCESS` value to indicate success. All error codes are in the form: `ADI_DEV_RESULT_XXXX`.

In addition to the return code, the `adi_dev_Init()` function returns a count of the number of device drivers it can manage simultaneously, and a handle into the device manager. The device count can be tested to ensure the device manager can control the requested number of device drivers.

Another parameter passed to the `adi_dev_Init()` function is a critical region parameter. When it is necessary to protect a critical region of code, the device manager and all physical drivers leverage the interrupt manager system service to protect the critical code. The critical region parameter passed into the `adi_dev_Init()` function is, in turn, passed to the `adi_int_EnterCriticalRegion()` function. Refer to "adi_int_Init" on page 2-18.

Device Manager Termination

When the device manager is no longer needed, the client can terminate it by means of the `adi_dev_Terminate()` function. This function is passed the device manager handle, given to the client in the `adi_dev_Init()` function. The device manager closes any open physical devices and then returns to the caller. After the return from the `adi_dev_Terminate()`

function, the client can reuse the memory that was supplied to the device manager via the `adi_dev_Init()` function. Once terminated, the device manager must be reinitialized in order to be used again.

In many embedded systems, the device manager is never terminated.

Opening a Device

After the device manager has been initialized, in order to use a device, the client must first open the device with the `adi_dev_Open()` API function.

The client passes in parameters indicating the device driver it wants to open (the `pEntryPoint` parameter), the instance of the device it wants to open (the `DevNumber` parameter), the direction it wants data to flow (inbound, outbound, or both), and so on. The client also passes in the handle to the DMA service the device manager and physical drivers to use. This parameter can be NULL if the client knows DMA is not used.

The `pDeviceHandle` parameter points to a location where the device manager stores the handle to the device driver that is being opened. All subsequent API calls for this device that is being opened must include this handle. The `ClientHandle` is a parameter that the device manager passes back to the client with each call to the client's callback function.

Two other parameters are passed into the `adi_dev_Open()` function. They are also callback-related. The `DCBHandle` parameter is a handle to the deferred callback service that is used by the device driver to call the client's callback function. If `DCBHandle` is non-NULL, the device driver uses the specified deferred callback service for all callbacks. If `DCBHandle` is NULL, all callbacks are live; meaning they are not deferred and are executed immediately (typically at interrupt time). The `ClientCallback` parameter points to the client's callback function.

The callback function is called in response to asynchronous events experienced by the device driver. Some events may be expected, such as completing the processing of a buffer, and some events may be unexpected, such as a device generating an error condition. Regardless of the type of event, the device manager calls the callback function to notify the client of the event.

Dataflow through a device does not start with the `adi_dev_Open()` function. This function simply opens the device for use; the device may need to be configured in some way before dataflow is enabled.

Configuring a Device

The `adi_dev_Control()` function is used to configure and enable/disable dataflow through a device. When opened, most device drivers initialize with some default settings. If these default settings are sufficient for the application, little or no application configuration is required. At other times, the default settings may not be appropriate for an application, so the device needs some configuration. The `adi_dev_Control()` function is used to set and detect device-specific configurations.

When configuration settings need to be set or detected, the client calls the `adi_dev_Control()` function to set or detect the parameter. This function takes as parameters the `DeviceHandle` (described in "Opening a Device"), a command ID that identifies the parameter to set or detect, and a pointer to the memory location that contains the value of the parameter to set (or where the value of the parameter detected is stored). The device manager defines some standard parameters; however, physical drivers are free to add their own command IDs beyond those defined by the device manager. For example, the physical device driver for a DAC may create a command ID to set the volume level of the output.

ⓘ The application developer should check the physical driver documentation to determine which parameters are configurable and the configuration choices.

Regardless of whether the client needs to make configuration changes, the client must make two calls into the `adi_dev_Control()` function. These calls set the dataflow method of the device and enable dataflow for the device. These are described in the following sections.

Dataflow Method

The device manager supports three dataflow methods: circular, chained, and chained with loopback. Prior to providing the device manager with any buffers or enabling dataflow, the application must inform the device manager of the dataflow method to use by calling the `adi_dev_Control()` function with the `ADI_DEV_CMD_SET_DATAFLOW_METHOD` command. After the dataflow method has been defined, the client can provide inbound buffers (via the `adi_dev_Read` function) or outbound buffers (via the `adi_devWrite` function) to the device.

As shown in Figure 10-2, the circular dataflow method defines the method whereby a single circular buffer is provided to the device manager, assuming the device was opened for unidirectional traffic.

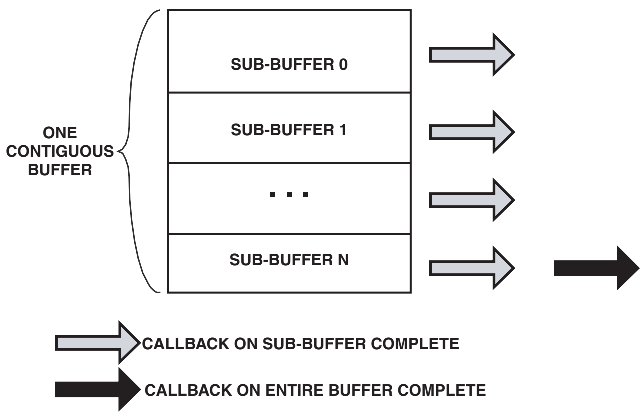


Figure 10-2. Circular Buffer Operation

When providing the device manager with the circular buffer, the application informs the device manager of how many sub-buffers are within the circular buffer; two sub-buffers are used for a traditional “ping-pong” scheme, though Blackfin processors support any number of sub-buffers. The application also tells the device manager when it wants to be called back during processing of the circular buffer.

Three options are provided: no callback ever, callback after processing each sub-buffer, and callback after processing the entire buffer. The device manager begins processing at the start of the buffer. When directed, the device manager notifies the application via the callback function when each sub-buffer completes or when the entire buffer has completed processing. After reaching the end of the buffer, the device manager automatically restarts processing at the top of the buffer and so on.

As shown in Figure 10-3, with the chained dataflow method, one or more one-dimensional and/or two-dimensional buffers are provided to the device manager. Any number of buffers can be provided; buffers can be of different sizes, and both one-dimensional and two-dimensional buffers can be provided to the same device. Each buffer, any one buffer, none, or all buffers can be tagged to generate a callback to the application when they are processed. Additional buffers can be provided at any time before or after dataflow has been enabled. The device manager guarantees to process the buffers in the order they are provided to the device manager.

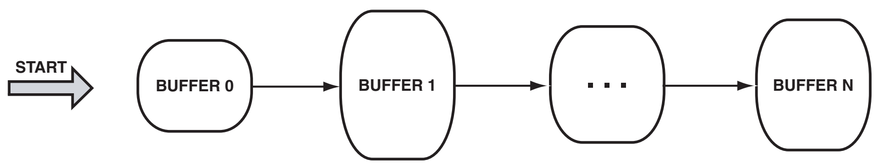


Figure 10-3. Chained Buffers

When using the chained dataflow method, the application can command the device manager to operate in synchronous mode. Normally, the device manager operates in asynchronous mode. In asynchronous mode, the adi_dev_Read and adi_dev_Write function calls return immediately to the application before all the buffers passed to the adi_dev_Read or adi_dev_Write function have been processed. In synchronous mode, the adi_dev_Read and adi_dev_Write functions do not return back to the application until all buffers provided to the adi_dev_Read or adi_dev_Write function have been processed. Though seldom used in real-time systems, the device manager also supports synchronous operation.

As shown in Figure 10-4, the chained with loopback method is similar to the chained dataflow method except that after processing the last buffer, the device manager automatically loops back to the first buffer that was provided to the device. This operation effectively creates an infinite loop of buffers. With the chained with loopback method, the application can provide the buffers at initialization time, allow the device manager to process the buffers, and never have to resupply the device manager with additional buffers. As with the chained dataflow method, each buffer, any one buffer, none, or all buffers can be tagged to generate a callback to the application when they are processed.

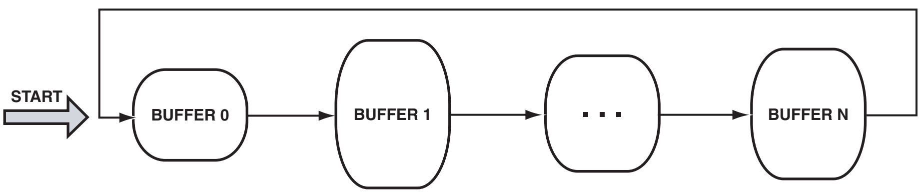


Figure 10-4. Chained Buffers With Loopback

Enabling Dataflow

Once the dataflow method has been defined, and buffers provided to the device as appropriate (see “Providing Buffers to a Device”), the application enables dataflow by calling the `adi_dev_Control` function with the `ADI_DEV_CMD_SET_DATAFLOW` command. Dataflow starts immediately so the application should ensure that, if not using synchronous mode, devices that are opened for inbound or bidirectional data are provided with buffers, or else data may be lost.

Providing Buffers to a Device

Buffers are provided to a device via the `adi_dev_Read` and `adi_dev_Write` API function calls. The `adi_dev_Read` function provides buffers for inbound data, `adi_dev_Write` for outbound data. How the client provides buffers to the device via these API calls is slightly different depending on the dataflow method chosen.

When a device is configured to use the circular dataflow method, the application provides the device driver with one and only one buffer for inbound data and/or one and only one buffer for outbound data. The data provided buffer points to a contiguous piece of memory corresponding to however many sub-buffers the application wants to use.

For example, assume the application wants to process data in 512-byte increments and wants to work in a traditional “ping-pong” type (two sub-buffer) fashion. The application provides the device driver with a single data buffer 1024 bytes in length, consisting of two 512-byte sub-buffers. By doing this, the device driver can use 512 bytes of the buffer while the application uses the other 512 bytes simultaneously.

Another example is an application that wants to process a standard NTSC video frame (525 lines with 1716 bytes per line). The data buffer provided to the device manager could be a contiguous piece of memory `900900` bytes in size (`525 * 1716`). The sub-buffer count in this case is 525. Regardless of how many sub-buffers are provided, with the circular dataflow method, once the buffer has been provided to the device driver, the application never needs to give the device another buffer, as the same one is used indefinitely.

When a device is configured to use the chained dataflow method, any number of one-dimensional and two-dimensional buffers can be provided to the device. Buffers can be given to the device one at a time, or multiple buffers can be provided with a single call to `adi_dev_Read` and/or `adi_dev_Write`. The application can provide the device driver with additional buffers at any time before (or even after) dataflow is enabled. Assuming the device driver is running in asynchronous mode, any individual buffer, no buffers, or all buffers can be flagged to generate a callback when the device driver has completed processing it. Each buffer can be of a different size, and both one-dimensional and two-dimensional buffers can be provided to the same device.

Providing buffers to devices configured with the chained-with-loopback dataflow method is identical to providing buffers to devices using the chained dataflow method, except that buffers can only be provided while dataflow is disabled.

Closing a Device

When the device is no longer needed by the client, the device is closed via the `adi_dev_Close` API function call. The `adi_dev_Close` function terminates dataflow if it is enabled and frees up all resources, including DMA and others used by the device driver. Should the application need to reuse the device after it is closed, it can be reopened via the `adi_dev_Open` function.

Callbacks

The device manager calls the application's callback function to notify the client of occurring events. Events include expected events (such as completion of buffer processing) or unexpected events (such as an error occurring on a device). Typically, the client's callback function is organized as the equivalent of a C switch statement, invoking the appropriate processing as required by the given event type. The device manager defines several events and physical drivers can add additional events as required by the device they are controlling.

Initialization Sequence

Because the device manager and physical drivers rely on system services, it should be initialized prior to opening a device driver. For example, when opening a device driver, the device manager requires handles to the deferred callback and DMA services (assuming both are used). As such, it is good practice to initialize and open the system services before opening any device drivers. See "Initialization" on page 1-10 and "Termination" on page 1-24 for more information on initializing and terminating the device drivers and system services.

Stackable Drivers

It is possible to create drivers that call other drivers. For example, the Blackfin EZ-KIT Lite board contains an AD1836 audio codec. This codec has a control and status interface that is suitable for connection to an SPI port, while the AD1836 audio data is provided to/from the device by using a high-speed serial line (in this case, the SPORT peripheral). If a system is developed in which the AD1836 codec is the only device that would ever be connected to the processor, a single physical device driver could be written to control and manage the SPI and the SPORT.

Alternatively, the SPI port could hierarchically sit above the SPI and SPORT drivers, making calls into those physical drivers as necessary. It is especially true if other peripherals are to share the SPI port (for example, separate SPI and SPORT drivers could be controlled by an AD1836 driver). In this stackable fashion, it is possible to create more complex drivers such as the AD1836 driver or a TCP/IP stack driver that sit on top of an Ethernet controller.

Deciding on a Dataflow Method

When using device drivers, you should give thoughtful consideration when choosing the dataflow method to be used for each device driver. Some types of data are better suited to one type of dataflow method, and other types of data may be more suitable for another dataflow method. As a rough guideline, you may want to consider the following situations when selecting a dataflow method to use for a device driver.

Chained Without Loopback

The chained-without-loopback dataflow method is suitable for packet-based data that may be sent and/or received in a non-continuous or "bursty" manner. For example, UART data from a terminal, Ethernet data, and USB traffic frequently use the chained-without-loopback dataflow method.

Chained With Loopback

The chained-with-loopback dataflow method is suitable for steady, continuous dataflow. For example, streaming audio and video applications frequently use the chained-with-loopback dataflow method. With this method, buffers are provided at initialization time. Because loopback is used, the application never needs to re-supply the driver with additional buffers, since the driver continually loops through the same set of buffers.

Circular

When using streaming audio or video, the streaming sub-mode is highly recommended to avoid clicks and pops with audio data and glitches on video data.

The circular dataflow method is suitable for steady, continuous dataflow, where the entire data fits in a 64K byte maximum contiguous block of memory. Streaming audio data, assuming it fits within the 64 K byte block of memory, is sometimes appropriate for the circular dataflow method. This saves the overhead of having to create multiple buffers as is necessary using the chained-with-loopback method. Generally, video data is not appropriate for the circular dataflow method, since video data is frequently larger than the 64K byte maximum for circular dataflow.

Sequential With and Without Loopback

The sequential dataflow method, with and without loopback, is suitable only for devices that employ half-duplex, serial type communication protocols. For example, the two-wire interface (TWI) device driver uses the sequential dataflow methods to precisely schedule reads and writes in a specific order.

Creating One-Dimensional Buffers

The `ADI_DEV_1D_BUFFER` data structure is used to describe a linear array of data that a device driver processes. Applications populate the various fields of the buffer to completely describe the data to the device driver. For one-dimensional buffers, applications populate the following fields of the `ADI_DEV_1D_BUFFER` structure:

- `Data` – If the buffer is provided to the `adi_dev_Write()` function, this field contains the starting address of the data sent out through the device. If the buffer is provided to the `adi_dev_Read()` function, this field contains the starting address of where the device driver stores data received in from the device.

- `ElementCount` – This field indicates the number of elements pointed to by the data pointer.

- `ElementWidth` – This field indicates the width (in bytes) of each element sent out or read in.
- `CallbackParameter` – If this field is NULL, the device driver does not call back the application after the device driver processes the buffer. If non-NULL, the device driver invokes the application's callback function after the buffer is processed by the device driver, passing this value as the third parameter to the callback function.
- `pNext` – This field points to the next one-dimensional buffer in the chain, if any. If NULL, the given buffer is the only buffer provided to the `adi_dev_Read()` or `adi_dev_Write()` function.
  If non-NULL, this field contains the address of the next one-dimensional buffer in the chain of buffers passed to the `adi_dev_Read()` or `adi_dev_Write()` function.
- `pAdditionalInfo` – This field is a device driver-dependent value. This field is not used for most device drivers. For information describing whether this field is used by the particular device driver, refer to the documentation specific to the device driver, located in the …`/Blackfin/doc` subdirectory.
- `ProcessedFlag` – Some device drivers set this value to TRUE after processing the buffer. For information describing whether this field is used by the particular device driver, refer to the documentation specific to the device driver, located in the …`/Blackfin/doc` subdirectory.

When buffers are submitted to the device driver via the `adi_dev_Read()` or `adi_dev_Write()` functions, some device drivers do not require the following fields be populated:

- `ProcessedFlag` – Some device drivers set this value to TRUE after the device driver processes the buffer. For information describing whether this field is used by the particular device driver, refer to the documentation specific to the device driver, located in the `…/Blackfin/doc` subdirectory.
- `ProcessedElementCount` – Some device drivers set this value to the number of elements processed by the driver for the given buffer. For example, if a networking driver submitted a buffer describing 100 bytes of data to the `adi_dev_Read()` function for an incoming data packet that contains only 75 bytes of data, the driver may set this value to 75. This would indicate that although 100 bytes was requested, only 75 bytes were available. For information describing whether this field is used by the particular device driver, refer to the documentation specific to the device driver, located in the `…/Blackfin/doc` subdirectory.

For example, the following code fragment prepares and submits a single buffer of 128 16-bit elements to the `adi_dev_Read()` function. The driver calls back the application when the buffer has been processed, passing the value 0x12345678 as a parameter to the callback function.

```
#define SAMPLES_PER_BUFFER  (128)     // number of samples
                                      // in a data buffer

static u16 Data[SAMPLES_PER_BUFFER];  // storage for data
static ADI_DEV_1D_BUFFER Buffer;      // the actual buffer

            // create buffer for the driver to process
Buffer.Data              = Data;
Buffer.ElementCount      = SAMPLES_PER_BUFFER;
Buffer.ElementWidth      = 2;
```

```
Buffer.CallbackParameter = (void *)0x12345678;  // callback,
                                              // pArg = 0x12345678
Buffer.pNext              = NULL;  // only buffer in the chain

       // give the buffer to the driver to fill with data
       Result = adi_dev_Read(Handle, ADI_DEV_1D, (ADI_DEV_BUFFER
*)&Buffer);
```

The following code fragment prepares and submits a chain of four buffers, each describing 128 elements of 32-bit data, to the `adi_dev_Read()` function. The driver calls back the application after each buffer has been processed, passing the address of the buffer that just completed as a parameter to the callback function.

```
#define NUM_BUFFERS         (4)    // number of buffers to use
#define SAMPLES_PER_BUFFER (128)   // # of samples in data buffer
static u32 Data[NUM_BUFFERS*SAMPLES_PER_BUFFER];
                                     // storage for data
static ADI_DEV_1D_BUFFER   Buffer[NUM_BUFFERS];
                                     // the actual buffers

u32 i; // counter
     // create buffers for the driver to process
     for (i = 0; i < NUM_BUFFERS; i++) {
        Buffer[i].Data = &Data[i * SAMPLES_PER_BUFFER;]
        Buffer[i].ElementCoun       = SAMPLES_PER_BUFFER;
        Buffer[i].ElementWid        = 4;
        Buffer[i].CallbackParameter = &Buffer[i]; // gen call-
back, pArg = buffer address
        Buffer[i].pNext             = &Buffer[i+1];
                          // point to the next in chain
    }
     Buffer[NUM_BUFFERS - 1].pNext  = NULL;
                          // terminate the chain of buffers
```

```
    // give the buffers to the driver to fill with data
    Result = adi_dev_Read(Handle, ADI_DEV_1D, (ADI_DEV_BUFFER
*)Buffer);
```

Creating Two-Dimensional Buffers

Use the ADI_DEV_2D_BUFFER data structure to describe a two-dimensional array of data that a device driver processes. Applications populate the various fields of the buffer to completely describe the data to the device driver. For two-dimensional buffers, applications populate the following fields of the ADI_DEV_2D_BUFFER structure:

- Data – If the buffer is provided to the adi_dev_Write() function, this field contains the starting address of the data sent out through the device. If the buffer is provided to the adi_dev_Read() function, this field contains the starting address of where the device driver stores data received from the device.
- ElementWidth – This field indicates the width (in bytes) of each element sent out or read in.
- XCount – This field specifies the number of column elements.
- XModify – This field specifies the byte address increment (stride) after each column transfer.
- YCount – This field specifies the number of row elements.
- YModify – This field specifies the byte address increment (stride) after each row transfer.
- CallbackParameter – If this field is NULL, the device driver does not call back the application after the buffer is processed by the device driver. If non-NULL, the device driver invokes the

application's callback function after the buffer is processed by the device driver, passing this value as the third parameter to the callback function.

- `pNext` – This field points to the next two-dimensional buffer in the chain, if any. If NULL, the given buffer is the only buffer provided to the `adi_dev_Read()` or `adi_dev_Write()` function.
  If non-NULL, this field contains the address of the next two-dimensional buffer in the chain of buffer passed to the `adi_dev_Read()` or `adi_dev_Write()` function.

- `pAdditionalInfo` – This field is a device driver-dependent value. This field is not used for most device drivers. For information describing whether this field is used by the particular device driver, refer to the documentation specific to the device driver, located in the `…/Blackfin/doc` subdirectory.

When buffers are submitted to the device driver via the `adi_dev_Read()` or `adi_dev_Write()` functions, some device drivers do not require the following fields be populated:

- `ProcessedFlag` – Some device drivers set this value to TRUE after the device driver processes the buffer. For information describing whether this field is used by the particular device driver, refer to the documentation specific to the device driver, located in the `…/Blackfin/doc` subdirectory.

- `ProcessedElementCount` – Some device drivers set this value to the number of elements processed by the driver for the given buffer. For example, if a networking driver submitted a buffer describing 100 bytes of data to the `adi_dev_Read()` function for an incoming data packet that contains only 75 bytes of data, the driver may set this value to 75. This would indicate that although 100 bytes was requested, only 75 bytes were available. For information describing whether this field is used by the particular device driver, refer to the documentation specific to the device driver, located in the …/Blackfin/doc subdirectory.

For example, the following code fragment prepares and submits a pair of two-dimensional buffers to the adi_dev_Write() function for transmission out through the driver. Each buffer describes an NTSC ITU-656 frame of data. Each frame consists of 525 rows, each containing 1716 bytes of data. The driver calls back the application when each buffer has been processed, passing the address of the buffer that just completed as a parameter to the callback function.

```
#define NUM_BUFFERS (2)
#define NUM_FRAMES  (2)
#define COLUMNS     (1716)
#define ROWS        (525)

static u8 Frames[NUM_FRAMES][COLUMNS * ROWS];
                  // storage for data
static ADI_DEV_2D_BUFFER Buffer[NUM_BUFFERS];
                  // the actual buffer

u32 i; // counter

// create buffers for the driver to process
    for (i = 0; i < NUM_BUFFERS; i++) {

        Buffer[i].Data              = &Frames[i][0];
        Buffer[i].ElementWidth      = 2;
        Buffer[i].XCount            = (COLUMNS >> 1);
        Buffer[i].XModify           = 2;
        Buffer[i].YCount            = ROWS;
        Buffer[i].YModify           = 2;
        Buffer[i].CallbackParameter = &Buffer[i];
                      // gen callback, pArg = buffer address
```

```
        Buffer[i].pNext             = &Buffer[i+1];
    }
    Buffer[NUM_BUFFERS - 1].pNext   = NULL;
                        // terminate the chain of buffers

    // give the buffers to the driver to send out
    Result = adi_dev_Write(Handle, ADI_DEV_2D, (ADI_DEV_BUFFER
*)Buffer);
```

Creating Circular Buffers

The ADI_DEV_CIRCULAR_BUFFER data structure is used to describe data that the driver processes in a circular manner. Applications populate the various fields of the buffer to completely describe the data to the device driver. For circular buffers, applications populate the following fields of the ADI_DEV_CIRCULAR_BUFFER structure:

- Data – If the buffer is provided to the adi_dev_Write() function, this field contains the starting address of the data sent out through the device. If the buffer is provided to the adi_dev_Read() function, this field contains the starting address of where the device driver stores data received in from the device.
- ElementWidth – This field indicates the width (in bytes) of each element sent out or read in.
- SubBufferCount – This field specifies the number of sub-buffers into which the data is divided.
- SubBufferElementCount – This field specifies the number of elements in each sub-buffer.

- `CallbackType` – This field specifies the frequency of callbacks that the application desires and contains one of the following:
  - `ADI_DEV_CIRC_NO_CALLBACK` – No callbacks
  - `ADI_DEV_CIRC_SUB_BUFFER` – Call back after completion of each sub-buffer
  - `ADI_DEV_CIRC_FULL_BUFFER` – Call back only after completion of the entire buffer
- `pAdditionalInfo` – This field is a device driver-dependent value. This field is not used for most device drivers. For information describing whether this field is used by the particular device driver, refer to the documentation specific to the device driver, located in the …`/Blackfin/doc` subdirectory.

For example, the following code fragment prepares and submits a circular buffer for transmission out through the device driver via the `adi_dev_Write()` function. The buffer describes a contiguous block of 1024 bytes of memory that is divided into 8 sub-buffers of 128 bytes each. The driver calls the application back after each sub-buffer is processed. Once dataflow is enabled, the driver repeatedly processes the circular buffer until dataflow is terminated.

```
#define SUB_BUFFERS         (8)
#define SUB_BUFFER_ELEMENTS (128)

static u8 Data[SUB_BUFFERS * SUB_BUFFER_ELEMENTS];
                                        // storage for data
static ADI_DEV_CIRCULAR_BUFFER Buffer;  // the actual buffer

    // create buffer for the driver to process
    Buffer.Data                  = Data;
    Buffer.ElementWidth          = 1;
    Buffer.SubBufferCount        = SUB_BUFFERS;
    Buffer.SubBufferElementCount = SUB_BUFFER_ELEMENTS;
```

```
    Buffer.CallbackType         = ADI_DEV_CIRC_SUB_BUFFER;

    // give the buffer to the driver to send out
    Result = adi_dev_Write(Handle, ADI_DEV_CIRC, (ADI_DEV_BUFFER
*)&Buffer);
```

Creating Sequential One-Dimensional Buffers

The ADI_DEV_SEQ_1D_BUFFER data structure is used to describe a sequential, one-dimensional (linear) array of data that a device driver processes. Similar to the standard one-dimensional buffers, applications populate the various fields of the buffer to completely describe the data to the device driver. In fact, a sequential, one-dimensional buffer is a concatenation of a standard one-dimensional buffer with a direction field appended to the end of the standard buffer. For sequential, one-dimensional buffers, applications populate the following fields of the ADI_DEV_SEQ_1D_BUFFER structure:

- Buffer – The buffer entry, which is identical to the standard one-dimensional buffer, is populated exactly as the standard one-dimensional buffer. Refer to "Creating One-Dimensional Buffers" on page 10-19 for information on populating a standard one-dimensional buffer.

- Direction – This field is populated with one of the following choices:

  - ADI_DEV_DIRECTION_INBOUND – Populate the field with this value if the buffer is for data received in from the device.

  - ADI_DEV_DIRECTION_OUTBOUND – Populate the field with this value if the buffer is for data that is transmitted out through the device.

The following code fragment prepares and submits a chain of two buffers. The first and third buffers describe data sent out through the device, and the second and fourth buffers describe data that is read in from the device. The driver cals back the application after the last buffer in the chain is processed, passing the address of the buffer that just completed as a parameter to the callback function.

```
#define ELEMENT_WIDTH     (1)
                         // width of a data element
#define NUM_BUFFERS       (2)     // number of buffers
#define INBOUND_ELEMENTS  (64)
                         // number of elements to read in
#define OUTBOUND_ELEMENTS  (2)
                         // number of elements to write out

static u32 InboundData[INBOUND_ELEMENTS];  // inbound data
static u32 OutboundData[OUTBOUND_ELEMENTS];
                                          // outbound data

// the actual buffers
static ADI_DEV_SEQ_1D_BUFFER SeqBuffer[NUM_BUFFERS];

   // create outbound buffer for the driver to process
   SeqBuffer[0].Buffer.Data            = OutboundData;
   SeqBuffer[0].Buffer.ElementCount   = OUTBOUND_ELEMENTS;
   SeqBuffer[0].Buffer.ElementWidth   = ELEMENT_WIDTH;
   SeqBuffer[0].Buffer.CallbackParameter = NULL;
             // no callback
   SeqBuffer[0].Buffer.pNext = (ADI_DEV_1D_BUFFER
*)&SeqBuffer[1];
   SeqBuffer[0].Direction = ADI_DEV_DIRECTION_OUTBOUND;

    // create inbound buffer for the driver to process
   SeqBuffer[1].Buffer.Data     = InboundData;
   SeqBuffer[1].Buffer.ElementCount = INBOUND_ELEMENTS;
```

```
    SeqBuffer[1].Buffer.ElementWidth = ELEMENT_WIDTH;
    SeqBuffer[1].Buffer.CallbackParameter = &SeqBuffer[1];
            // callback
    SeqBuffer[1].Buffer.pNext = NULL;     // end of chain
    SeqBuffer[1].Direction = ADI_DEV_DIRECTION_INBOUND;

        // give the buffers to the driver

    Result = adi_dev_SequentialIO(Handle, ADI_DEV_SEQ_1D,
  (ADI_DEV_BUFFER *)SeqBuffer);
```

Device Manager Design

The device manager provides the single point of access into the device driver model. The device manager provides the application with the API into the device drivers. All interaction between the client and device drivers occurs through the device manager—**applications never communicate directly with a physical driver**. The device manager also provides all DMA control, sequencing, queuing, and so on, for devices that are supported by peripheral DMA.

Users typically do not need to understand the design and implementation details of the device manager. This section is included for those users who want a deeper understanding of the design. This section is particularly useful for writers of physical drivers who need this information to aid in the development of physical drivers.

Device Manager API Description

The macros, definitions, and data structures defined by the device manager API are key to understanding the design of the device manager. The device manager API is described in the `adi_dev.h` file, which is located in the `Blackfin/Include/Drivers` directory.

The "Device Manager Public Data Types and Enumerations" section of this chapter contains tables for all the device manager data structures and enumerations.

Memory Usage Macros

The first section in the `adi_dev.h` file contains macros that define the amount of memory usage by the device manager. These macros can be used by the client to determine how much memory is allocated to the device manager via the `adi_dev_Init` function.

The `ADI_DEV_BASE_MEMORY` macro defines the number of bytes that the device manager needs. The `ADI_DEV_DEVICE_MEMORY` macro defines the number of bytes the device manager needs to control each physical driver. When providing memory to the device manager, the client provides the following amount of memory:

```
ADI_DEV_BASE_MEMORY + (n * ADI_DEV_DEVICE_MEMORY)
```

where "`n`" is the maximum number of physical drivers that are opened simultaneously in the system.

Handles

Next in the `adi_dev.h` file are `typedef` statements for the various handle types used by the device manager. Typically, handles are pointers to data structures used within the device manager. They are used as a means to identify the data pertaining to the device being managed quickly.

Dataflow Enumerations

Next in the `adi_dev.h` file are enumerations for the various dataflow methods supported by the device manager and enumerations indicating dataflow direction. These enumerations are not extensible by physical drivers.

Command IDs

The next section in the adi_dev.h file enumerates the command IDs that are defined by the device manager. These command IDs are passed to the device manager via the adi_dev_Control function.

Physical drivers can add any number of additional command IDs that are relevant to their particular device. Physical drivers begin adding their own command IDs starting with the enumeration start value for the driver.

Also included in this section is a data structure defining a configuration command pair. This is provided as a convenience—it allows clients to pass a table of commands into the adi_dev_Control function, rather than being forced to call the adi_dev_Control function for each command (see "adi_dev_Control" on page 10-59).

Callback Events

The next section in the adi_dev.h file contains enumerations for callback events. When an event occurs, the client's callback function is invoked and passed the enumeration of the event that occurred.

The device manager defines some common events. Similar to command IDs, physical drivers can add their own callback events beginning with the enumeration start value for the driver.

Return Codes

The next section in the adi_dev.h file contains enumerations for return codes. All API functions within the device manager return a code, indicating the results of the function call.

The device manager defines some typical return codes. Similar to command IDs and callback events, physical drivers can add their own return codes beginning with the enumeration start value for the driver.

Circular Buffer Callback Options

The next section in the adi_dev.h file contains enumerations for the type of callback the client requests when the device manager is using the circular buffer dataflow method.

Enumerations are provided indicating the device manager should make no callbacks, make a callback on sub-buffer completions, or make a callback on whole buffer completions.

Buffer Data Types

The ADI_DEV_1D_BUFFER, ADI_DEV_2D_BUFFER, and ADI_DEV_CIRCULAR_BUFFER data structures are used to provide data buffers to the driver. At the top of these data structures is a reserved area that allows the device drivers access to a small amount of memory attached to each buffer. How (or if) the device driver uses this reserved area depends on the implementation.

Note that if the physical device driver is supported by peripheral DMA, the device manager uses this reserved area to create a DMA descriptor describing the buffer. This descriptor is, in turn, passed to the DMA manager system service in order to use DMA to move the data, as described in the buffer structure.

If the physical driver is not supported by peripheral DMA, the physical driver can use this reserved area for any purpose—for example, queue management or whatever mechanism the physical driver uses to move the data.

Also included in this section is a ADI_DEV_BUFFER data structure, which represents a union of one-dimensional, two-dimensional, and circular buffers. This data type is used as a convenient method to refer to a buffer in a generic fashion, without knowing the specific type of buffer. The adi_dev_Read and adi_dev_Write API functions use the ADI_DEV_BUFFER data type when passing buffers to these functions.

Physical Driver Entry Point

The next section in the adi_dev.h file contains a data structure that describes the entry point into a physical driver. The structure ADI_DEV_PDD_ENTRY_POINT is simply a data type that points to the functions within the physical driver that are called by the device manager.

API Function Definitions

The last section in the adi_dev.h file describes the API calls into the device manager. Each function is declared here with the appropriate parameters for each call. Each function is described in detail in "Device Manager API Reference" on page 10-57.

Device Manager Code

All code for the device manager is kept in the adi_dev.c file. This section describes the code of the device manager. This file is located in the Blackfin/Lib/Src/Drivers directory.

Data Structures

The only additional data structures that are defined are the ADI_DEV_MANAGER and ADI_DEV_DEVICE structures. These structures contain all the data necessary for operation of the device manager itself and for management and control of the physical driver.

Static Data

The device manager uses a single piece of static data. The InitialDeviceSettings item is copied into an ADI_DEV_DEVICE structure when a device is opened. This provides a quick and efficient means to initialize an ADI_DEV_DEVICE structure without having to populate each item individually.

Static Function Declarations

This section declares static functions that are used within the device manager. Each of these functions is described in detail in sections that follow. Only the API functions are declared to be global; all other functions are static to the device manager.

API Functional Description

This section describes the functionality that is performed for each of the API functions in the device manager. The API functions include:

- `adi_dev_Init`
- `adi_dev_Open`
- `adi_dev_Close`
- `adi_dev_Read`
- `adi_dev_Write`
- `adi_dev_Control`

Refer to "Device Manager API Reference" on page 10-57 for more API information.

adi_dev_Init Functional Description

The `adi_dev_Init` function is used to initialize the device manager. For detailed reference information, see "adi_dev_Init" on page 10-60.

Processing begins by checking to ensure enough memory is provided to operate the device manager. The function then determines how many physical devices can be controlled with the remaining memory provided.

The critical region pointers are then stored, and the data structure for each device that can be supported is marked as available for use. The function then returns to the caller.

adi_dev_Open Functional Description

The adi_dev_Open function is used to open a device for use. For detailed reference information, see "adi_dev_Open" on page 10-61.

Processing begins by finding a free ADI_DEV_DEVICE data structure used to control the device. The address of that data structure is stored in the client-provided location as the handle to the device.

The ADI_DEV_DEVICE structure is initialized and populated with the information describing the device.

Once the ADI_DEV_DEVICE structure is initialized, the device manager calls the adi_pdd_Open function of the physical driver. The physical driver then executes, doing whatever it needs to do to open the device it controls. If the physical driver fails to open the device, the device manager frees up the ADI_DEV_DEVICE structure and returns the return code from the physical device back to the application. Note that because the return code values can be extended by the physical device, the return code can be as specific as possible as to why the device failed to open.

If the physical device opens correctly, the device manager interrogates the physical device to determine whether it is supported by peripheral DMA. The device manager saves this information in the ADI_DEV_DEVICE structure.

adi_dev_Close Functional Description

The adi_dev_Close function is called by the application when the device is no longer needed. For detailed reference information, see "adi_dev_Close" on page 10-58.

After the device handle is validated, assuming error checking is enabled, the function calls the adi_pdd_Control function of the physical driver to terminate dataflow. Once dataflow is terminated, any DMA channels that were opened for the device are closed. The adi_pdd_Close function of the physical driver is then called to shut down the device and to free up any resources used by the physical device. Lastly, the ADI_DEV_DEVICE structure is flagged as closed so that it may be reused later.

adi_dev_Read Functional Description

The adi_dev_Read function is called by the application to provide the device with buffers into which inbound data is stored. Assuming error checking is enabled, processing begins in this function by validating the device handle and ensuring that the device is open for inbound (or bidirectional) traffic and that the dataflow method is defined. If the dataflow method is not yet defined, the device manager does not have enough information to know what to do with the buffer. For detailed reference information, see "adi_dev_Read" on page 10-63.

The pBuffer parameter passed into the function can point to a single buffer or a chain of buffers. Furthermore, if the device is supported by peripheral DMA, the reserved area within the buffer data structure must be configured appropriately. All of these details are taken care of in the PrepareBufferList static function (see "PrepareBufferList" on page 10-43 for more information on this function).

Once the buffer list is prepared, a check is made to see whether the device is supported by peripheral DMA. If so, the DMA manager is called to queue the buffers on the proper DMA channel using the appropriate dataflow method—chained descriptors are passed to the DMA manager via the adi_dma_Queue function, and circular buffers passed via the adi_dma_Buffer function. If peripheral DMA is not supported, the buffers are passed directly to the physical driver using the adi_pdd_Read function. Note that when a device is supported by peripheral DMA, the physical driver is extremely simple because the device manager handles all data buffers for the physical device.

Lastly, a check is made to see if the device is operating in synchronous or asynchronous mode. If it is operating in asynchronous mode, the adi_dev_Read function returns to the application immediately. If it is operating in synchronous mode, the adi_dev_Read function waits in a loop until the buffer (or the last buffer within the list of buffers, if multiple buffers were provided as a parameter) is processed before returning to the application. Again, the physical driver has no knowledge of (nor the need for) the synchronous/asynchronous mode information.

adi_dev_Write Functional Description

The adi_dev_Write function operates virtually identically to the adi_dev_Read function, except the data is destined for the outbound rather than inbound direction. For detailed reference information, see "adi_dev_Write" on page 10-65.

adi_dev_Control Functional Description

The adi_dev_Control function is used to process configuration-type commands from the application. Like all the API functions, if error checking is enabled, the device handle is validated upon entry into the function. For detailed reference information, see "adi_dev_Control" on page 10-59.

Processing within the adi_dev_Control function is based upon the command ID passed in as a parameter. Some commands can be processed entirely by the device manager, some commands are processed by the physical driver only, and other commands need to be processed by both the device manager and the physical driver. In order to accomplish this, the bulk of this function is designed as a C switch statement. Each command that the device manager cares about has an entry in the statement.

When a command is passed that the device manager needs to process, the device manager processes the command and then sets a flag, stating whether the command needs to pass down to the physical driver. When processing gets to the bottom of the function, if the command needs to be passed to the physical driver, the adi_pdd_Control function of the physical driver is called and the return code from the physical driver is passed back to the application. This allows each physical driver to extend the command IDs and allows them to create their own unique command IDs that the application can control.

The device manager processes the following commands:

- `ADI_DEV_CMD_GET_2D_SUPPORT` – This command is used to determine if the device supports two-dimensional data movement. On Blackfin processors, if a device is supported by peripheral DMA, two-dimensional data movement is provided. If the device is not supported by peripheral DMA, the command is passed to the physical driver for determining if the physical driver can support two-dimensional data.

- `ADI_DEV_CMD_SET_SYNCHRONOUS` – This command is used to put the device manager in synchronous mode for the given device. The only processing here is to set the flag in the `ADI_DEV_DEVICE` structure. This command is never passed to the physical driver, as all synchronous activity is controlled by the device manager. Hiding this from the physical driver has the added benefit of physical drivers not caring (nor having to take special processing) to accommodate synchronous or asynchronous modes. The physical driver can operate in whatever manner is best suited to the device.

- `ADI_DEV_CMD_SET_DATAFLOW_METHOD` – This command is used to set the dataflow method for the given device. If the device is not supported by peripheral DMA, the device manager takes no action other than noting the dataflow method and passing the command along to the physical driver via the `adi_pdd_Control` function. If the device is supported by peripheral DMA, the default value used for the DMA configuration control register is updated with settings appropriate for the dataflow method. Further, once the dataflow method is defined by the application, the device manager then has enough information to open whatever DMA channels are necessary in support of the device. The physical driver is interrogated via the `adi_pdd_Control` function as to which DMA controller and channel number the device has been assigned for inbound and/or outbound data. The DMA manager is then accessed to open the appropriate channels with the appropriate modes, such as circular or chained descriptors. If the device is opened with the `ADI_DEV_MODE_CHAINED_LOOPBACK` dataflow method, the DMA manager is so configured. Note that the `ADI_DEV_DEVICE` structure is kept updated with the appropriate information as to which controllers and channels are opened or closed, what the operating modes are, and so on.

- `ADI_DEV_CMD_SET_DATAFLOW` – This command is issued to enable or disable dataflow on a device. The logic involved to enable or disable dataflow is fairly complex and isolated in a static function called `SetDataflow` (see "SetDataflow" on page 10-44 for more information on this function).

- `ADI_DEV_CMD_SET_STREAMING` - This command is issued to enable or disable the streaming mode of the device driver. (To fully understand what the streaming mode operation entails, users should be familiar with the streaming capability of the DMA manager system service, as described in "DMA Manager" on page 6-1. Though peripheral DMA support is not required of a device that supports streaming, devices that are supported by peripheral DMA automatically leverage the streaming capabilities of the DMA manager.)

  When streaming mode is enabled, the device is configured to treat data coming into and/or out of the device as a continuous stream of data. Typically, this allows the device driver to transmit and receive data through the device at maximum speed.

  In order to use the streaming mode of the device manager, the application must ensure that the following conditions are met:

  - The device always has buffers to process and never runs out of buffers. This means the application guarantees devices that are opened for inbound or bidirectional dataflow always have a buffer in which to store data that is received, and devices that are opened for outbound or bidirectional dataflow always have a buffer to transmit out through the device.

- The system timing is such that the device manager can acknowledge and service callbacks for a buffer before a callback for another buffer on that same device and going in that same direction (inbound or outbound) is generated.

These conditions can be fairly easily met in most systems.

Static Functions

This section describes the static functions within the device manager that are used in support of the API functions.

PDDCallback

The `PDDCallback` function is called in response to events from the physical driver. After error checking the device handle (if error checking is enabled), the device manager simply passes these events back to the application.

Note that in this routine (and the `DMACallback` function) the device manager calls the client callback function directly, regardless of whether live callbacks are in effect. It can do this as the physical driver is passed the handle to the deferred callback service as part of the `adi_pdd_Open` function.

As such, if the deferred callback service is in use, the invocation of the `PDDCallback` function in the device manager is deferred by the physical driver. In this way, the `PDDCallback` function can directly call the client's callback function.

DMACallback

The `DMACallback` function is called in response to DMA events from the DMA manager for devices that are supported by peripheral DMA. Assuming error checking is enabled, the device handle is validated first. The function then determines the event that has occurred and performs its processing based on the event type.

If the event indicates that a descriptor has been processed, the processed flag and processed count fields of the buffer are updated. The application's callback function is then invoked in order to notify the application of the event.

If the event indicates that DMA processing has generated the `ADI_DEV_EVENT_SUBBUFFER_PROCESSED` event, the function makes the appropriate callback into the application, stating that a sub-buffer has completed processing. If the event indicates that DMA processing has generated the `ADI_DEV_EVENT_BUFFER_PROCESSED` event, the function makes the appropriate callback into the application, stating that the entire buffer has completed processing.

The DMA manager reports asynchronous DMA errors via the callback mechanism. There errors are, in turn, passed back to the client via its callback function.

Note that in this routine (and the `PDDCallback` function), the device manager calls the client callback function directly, without concern for whether live callbacks are in effect. It can do this as the DMA manager is passed the handle to the deferred callback service as part of the `adi_dma_Open` function. As such, if the deferred callback service is in use, the invocation of the `DMACallback` function in the device manager is deferred by the DMA manager. In this way, the `dmaCallback` function can directly call the client's callback function.

PrepareBufferList

The `PrepareBufferList` function prepares a single buffer or list of buffers for submission to the DMA manager (when the device is supported by peripheral DMA) or the physical driver (when the device is not supported by peripheral DMA).

The function begins by determining the value of the direction field in the DMA configuration control register. Because the data structures for circular buffers, one-dimensional buffers, and two-dimensional buffers differ, each must be treated separately.

If passed as a circular buffer, the function assumes there is only one buffer in the buffer list. For devices opened with the `ADI_DEV_MODE_CIRCULAR` dataflow method, only a single buffer is provided so this is a valid assumption to make. The function configures the DMA configuration control register according to the parameters within the circular buffer data structure. The DMA configuration control register is set to generate inner-loop interrupts if the application wants to be called back when each sub-buffer has completed processing, or is set to generate outer-loop interrupts if the application wants to be called back when the entire buffer has completed processing, or neither if the application does not want any callbacks. The word size is set to the width of a data element in the buffer, and the direction field is set appropriately. The function then returns to the caller.

If the buffer type passed into the function specifies one-dimensional or two-dimensional buffers, the processing is largely the same except where noted.

For each buffer passed in, the processed flag and processed count fields within the buffer structure are cleared. If the physical device is supported by peripheral DMA, the reserved area at the beginning of each buffer structure is converted into a large model descriptor. The descriptor is then configured according to the parameters within the buffer structure, including such things as buffer size, width of an element, data direction, whether it is one-dimensional or two-dimensional, and so on.

The descriptor for each buffer in the chain is updated to point to the next descriptor for the corresponding buffer within the chain. The last descriptor in the chain, corresponding to the last buffer within the chain, is updated to point to NULL for the next descriptor. After processing is completed, a chain of buffers is established. All of the buffers are initialized appropriately, and the reserved area in each buffer contains a DMA descriptor for that buffer that, in turn, points to the DMA descriptor for the next buffer in the chain.

Lastly, if the device is opened for synchronous mode and peripheral DMA is supported, the last descriptor in the chain is forced to generate a callback from the DMA manager to the device manager. This allows the device manager to acknowledge when the last buffer has been processed so that it can update the processed fields appropriately. The last descriptor also acts as the trigger that responds each time the `adi_dev_Read` or `adi_dev_Write` function returns back to the application.

SetDataflow

The `SetDataflow` function is called in response to the `ADI_DEV_CMD_SET_DATAFLOW` command being received by the `adi_dev_Control` API function. This function enables or disables dataflow according to the flag.

The `SetDataflow` function begins processing by ensuring that the system is not trying to enable dataflow when it is already enabled or disable dataflow when it is already disabled. If this check is not performed, DMA and/or the physical drivers would likely generate errors.

When dataflow is being disabled, the function first calls the `adi_pdd_Control` function of the physical driver to disable dataflow. If the device is using peripheral DMA, it is important to disable dataflow at the device first, before shutting down DMA. Once the physical driver has disabled dataflow, any and all DMA channels that were opened for the device are closed. This is affected by calls to the DMA manager.

When dataflow is being enabled, if the device is supported by peripheral DMA, the function first enables dataflow on the DMA channels by making calls into the DMA manager to enable dataflow on the channel or channels that have been opened for the device. After the dataflow on the DMA channels has been enabled, the function calls the `adi_pdd_Control` function of the physical driver to enable dataflow.

Physical Driver Design

The physical driver is that part of the driver that controls the hardware for the device. Only the physical driver has knowledge of the device's control and status registers, and the fields within those registers. Unlike the device manager, in which there is only a single device manager in the system, any number of physical drivers can be present in a system.

Physical Driver Design Overview

Under application control, only the device manager communicates with each of the physical device drivers. Applications never interact directly with a physical driver or vice versa. However, similar to the execution sequence that applications have with the device manager, the device manager controls the physical device drivers in much the same manner. The device manager opens, controls, and closes physical device drivers analogous to how the application opens, controls, and closes the device manager.

Each physical driver in the system is controlled independently from the other physical drivers in the system. Although multiple physical drivers may exist simultaneously in a system, multiple physical drivers should never control the same device.

In general, a physical driver controls all instances of a device within a system. For example, if there are four serial ports (SPORTs) in the system, a single physical driver for the SPORT peripheral is capable of controlling all four serial ports individually and simultaneously.

The physical driver is responsible for hooking any and all interrupts as needed for the physical device. Many physical devices generate interrupts on error conditions. These interrupts are caught by the physical driver and passed back up as an event via the callback mechanism. The interrupt manager provides a very simple, straightforward mechanism that is used for all interrupt processing. This simplifies the task of porting device drivers to different operating environments, toolchains, and operating systems.

If a device is supported by peripheral DMA, the physical driver is greatly simplified as the device manager typically controls all DMA interaction, without any involvement from the physical driver. When a device is opened, the device manager interrogates the physical driver as to whether the device is supported by peripheral DMA. If the physical driver responds in the affirmative, the device manager controls all DMA activity (such as initialization, providing data buffers, callback mechanisms, and so on) via the DMA manager API. As such, the device manager never calls the `adi_pdd_Read` and `adi_pdd_Write` routines of a physical driver that is supported by peripheral DMA. Physical drivers for devices that are supported by peripheral DMA are quite simple to implement.

For devices that are not supported by peripheral DMA, physical drivers can still take advantage of the DMA manager, as memory DMA can be an effective strategy for reading/writing to devices that use programmed I/O. If directed to use deferred callbacks, physical drivers use the services of the deferred callback manager exclusively in order to post callbacks into the device manager. See “Deferred Callback Manager” on page 5-1 for more information.

Physical drivers have their own API, which is accessed by the device manager. The following sections describe the API and the functionality provided by the physical driver.

Physical Device Driver API Description

The API into a physical device driver is similar to the API between the device manager and the application in that there is a function in the physical driver API that maps to each function in the device manager API, except for `adi_dev_Init`. These functions are all prefixed with `adi_pdd` and are defined in the device manager include file (`adi_dev.h`).

The physical device driver functions are encapsulated in a structure called `ADI_DEV_PDD_ENTRY_POINT`. Each physical driver exports an entry point structure. The application passes the address of this structure to the device manager as part of the `adi_dev_Open` function call. The device manager, in turn, uses this data structure to call the individual routines in the physical driver. This mechanism allows multiple physical drivers to exist in the same system without causing name space conflicts.

There are five functions in the physical driver API. These functions are described in the sections that follow. The API functions include:

- `adi_pdd_Open` – Opens a device for use
- `adi_pdd_Close` – Closes a device
- `adi_pdd_Read` – Provides buffers for reception of data from a device
- `adi_pdd_Write` – Provides buffers containing data for transmission out the device
- `adi_pdd_Control` – Configures the device

Physical Driver Include File ("xxx.h")

The API for physical drivers is defined in the adi_dev.h include file of the device manager. However, physical drivers can extend some of the definitions and enumerations defined by the device manager. Additional command IDs, event IDs, and return codes can be created by each physical driver. These extensible definitions are described in the sections that follow. These definitions are normally defined in an include file provided with the physical driver. For example, the PPI driver, whose code is contained in the adi_ppi.c file, has a companion adi_ppi.h include file. The only contents of the include file are the extensible definitions that the physical driver makes available to the application.

Client applications should include the device manager adi_dev.h file and the include file for each of the physical drivers they will be using. For example, a client application using the PPI physical driver should include the adi_dev.h and adi_ppi.h include files. The adi_dev.h include file and physical driver include files for all Analog Devices-provided drivers are found in the Blackfin/Include/Drivers directory.

Extensible Definitions

The physical driver can define its own extensions to the command IDs, event IDs, and return codes, beyond those already defined by the device manager in the adi_dev.h file.

Physical drivers can create any number of additional command IDs. Applications can issue these command IDs via the adi_dev_Control API function. When the adi_dev_Control function of the device manager sees an extended command ID, the device manager passes the call onto the physical driver's adi_pdd_Control function, passing along the parameters provided by the application. This gives the physical driver the option of creating additional command IDs that are relevant to the device being controlled.

For example, a physical driver for a DAC may define a command ID that allows the application to set or detect the output volume level for the DAC.

In a similar fashion, physical drivers can create additional event IDs that they can pass back to the application. Physical drivers can create any number of additional event IDs. Physical drivers can send these events to the application via a callback to the device manager. When the device manager's `PDDCallback` function is passed an extended event ID, it passes the event and parameters passed to the device manager's callback function along to the application. This gives the physical driver the option of creating additional event IDs that are relevant to the device being controlled. For example, a physical driver that controls a device that is detecting the level of a signal can create an event that notifies the application when the signal has reached some predetermined value.

Physical drivers can also return custom-defined error codes. Physical drivers can create any number of additional return codes. These drivers can return these error codes in response to any physical driver API function call from the device manager. The device manager routinely looks for the `ADI_DEV_RESULT_SUCCESS` error code. Anything other than `ADI_DEV_RESULT_SUCCESS` is interpreted to be an error.

When a physical driver API function returns an error code not equal to `ADI_DEV_RESULT_SUCCESS`, the device manager passes the error code back to the application as the return value for the device manager API function that triggered the error. This gives the physical driver the option of creating additional return codes that are relevant to the device being controlled.

For example, a physical driver may return a unique error code in response to a command to affect a parameter on the device. The physical driver could return an error code that provides a high level of detail as to what caused the error.

The adi_dev.h file contains the starting enumeration values for each physical driver. Use this value as the starting value for all command IDs, event IDs, and return codes.

ADI_DEV_PDD_ENTRY_POINT

The physical driver's include function must include a declaration of the entry point into the driver. This declaration declares, as a global variable, the address of the entry point for the physical driver. The application passes the address of the entry point to the device manager when the device is opened. For example, the line

```
extern ADI_DEV_PDD_ENTRY_POINT PPIEntryPoint;
                    // entry point to the PPI driver
```

in the PPI driver's include file informs the application to pass the variable PPIEntryPoint as the entry point parameter in the adi_dev_Open function call to open the PPI device driver.

Physical Driver Source ("xxx.c")

All functions within the physical driver source code, including the actual physical driver API functions, are declared static so that they are not exposed to any other software components. The only global piece of code or data is the entry point address. The entry point is a simple structure that contains the addresses of the physical driver API functions in the following order.

```
ADI_DEV_PDD_ENTRY_POINT PPIEntryPoint = {
      adi_pdd_Open,
      adi_pdd_Close,
      adi_pdd_Read,
      adi_pdd_Write,
      adi_pdd_Control
};
```

Source code for all Analog Devices-supplied physical drivers is located in the `Blackfin/Lib/Src/Drivers` directory.

All code within the driver source is in support of the five physical driver API functions. These functions and the logic that they need to provide are described in sections that follow. All physical driver API functions must return an error code. The device manager checks the return code for every physical driver API call. If the physical driver returns anything other than `ADI_DEV_RESULT_SUCCESS`, it assumed to be some type of failure.

Similar to what is implemented in the device manager, it is highly recommended that physical drivers implement some type of switchable error checking, ideally using the `ADI_DEV_DEBUG` macro. As a minimum, physical driver handles (`ADI_DEV_PDD_HANDLE`) should be validated in each API function.

adi_pdd_Open Functional Description

The `adi_pdd_Open` function is called by the device manager in response to the application calling the `adi_dev_Open` function. Its purpose is to open the device for use. For detailed reference information, see "adi_pdd_Open Functional Description" on page 10-51.

The `adi_pdd_Open` function should first verify that the device being requested is available for use and supports the requested data direction. Appropriate error codes are returned if the device is unavailable or does not support the requested direction.

The device being controlled is initialized and flushed of any stray data or pending interrupts. Any interrupts that are required to be handled in support of the device are hooked. For devices that are supported with peripheral DMA, typically only the error interrupt need be hooked. The interrupt manager of the system services is used for all hooking of interrupts. Enabling/disabling of interrupts through the system interrupt controller (SIC) is also accomplished using the interrupt manager service calls.

The physical driver saves the handle to the callback service. If non-NULL (meaning that deferred callbacks are in use), the physical driver invokes all callbacks through the service identified by the callback service handle. If NULL (meaning all callbacks are live and not deferred), the physical driver calls the device manager's callback function directly when sending events.

The physical driver also saves the ADI_DEV_PDD_HANDLE value in the location provided by the device manager. The device manager passes this handle back to the physical driver in all other API function calls.

The adi_pdd_Open function returns ADI_DEV_RESULT_SUCCESS if successful.

adi_pdd_Control Functional Description

The adi_pdd_Control function is called by the device manager in response to the application calling the adi_dev_Control function. Its purpose is to process configuration-type commands from the device manager and client application. Like all the API functions, if error checking is enabled, the routine validates the physical driver handle upon entry into the function. For detailed reference information, see "adi_pdd_Control Functional Description" on page 10-52.

Processing within the adi_pdd_Control function is based upon the command ID that is passed in as a parameter. Of the command IDs enumerated by the device manager in the adi_dev.h file, as a minimum, physical drivers must process the following commands:

- ADI_DEV_CMD_SET_DATAFLOW – Turns on and turns off the flow of data through the device

- ADI_DEV_CMD_GET_PERIPHERAL_DMA_SUPPORT – Responds with TRUE or FALSE if the device is supported by peripheral DMA. If the device is supported by peripheral DMA, the adi_pdd_Control function is also prepared to respond to the following command IDs:
  - ADI_DEV_CMD_GET_INBOUND_DMA_PMAP_ID – Responds with the DMA peripheral map (PMAP) ID for the given device
  - ADI_DEV_CMD_GET_OUTBOUND_DMA_PMAP_ID – Responds with the DMA peripheral map (PMAP) ID for the given device

In most cases, the adi_pdd_Control function of the physical driver is constructed similarly to a C-style switch statement. Each command that the physical driver cares about, including the required command IDs listed above and any additional command IDs created by the physical driver itself, have an entry in the statement. If the physical driver receives a command ID that it does not understand, it typically returns the ADI_DEV_RESULT_NOT_SUPPORTED return code.

adi_pdd_Read Functional Description

The adi_pdd_Read function is called by the device manager in response to the application calling the adi_dev_Read function. Its purpose is to fill buffers with inbound data that is received from the device. With all API functions, if error checking is enabled, the routine validates the physical driver handle upon entry into the function. For detailed reference information, see “adi_pdd_Read Functional Description” on page 10-53.

For devices that are supported by peripheral DMA, the device manager manages all buffer queueing and reception. As a result, if the device is supported by peripheral DMA, the adi_pdd_Read function is never called by the device manager and no functionality need be provided by this routine. This greatly simplifies device drivers for devices that are supported by processor DMA. Physical drivers that are supported by peripheral DMA still need to provide this function but should simply return ADI_DEV_RESULT_NOT_SUPPORTED as this routine should never get called.

For devices that are not supported by peripheral DMA, the adi_pdd_Read function is passed one or more buffers that the application has provided for inbound data reception. The physical driver can choose to process the buffers immediately, or provide the logic and functionality to queue or somehow stage these buffers for use at a time. However, the physical driver is required to process the buffers in the order in which they were received.

For some devices, it may not be possible or practical to completely fill a buffer with data. For example, consider an Ethernet driver. The Ethernet driver typically receives packets that vary in length. The application may know what the maximum size Ethernet packet is and provide the driver with buffers sized to the maximum packet size. The driver may then receive a packet from the network that is smaller than the maximum packet size. It would be impractical for the physical driver to wait until additional packets were received and completely fill the buffer before processing. So, it is the physical driver's option to decide when to consider a buffer fully processed. Each buffer has a processed flag and processed size flag that the physical driver sets, based on when it considers a buffer processed and how much valid data the buffer contains.

Also, any buffer can be flagged by the application for notification when the buffer has completed processing. If a buffer is not flagged for a callback, the physical driver does not notify the device manager when the buffer is processed. If, however, the buffer is flagged for a callback (once the buffer is processed), the physical driver is obligated to set the processed flag and processed size field in the buffer, and to notify the device manager via the device manager's callback function that was passed to the physical driver as a parameter in the adi_pdd_Open function call, that the buffer has completed processing.

adi_pdd_Write Functional Description

The adi_pdd_Write function is called by the device manager in response to the application calling the adi_dev_Write function. Its purpose is to transmit the data within the buffers out through the device. For all API functions, if error checking is enabled, the routine validates the physical driver handle upon entry into the function. For detailed reference information, see "adi_pdd_Write Functional Description" on page 10-55.

As in the case for adi_pdd_Read, for devices that are supported by peripheral DMA, the device manager manages all buffer queueing and transmission. As a result, if the device is supported by peripheral DMA, the adi_pdd_Write function is never called by the device manager and no functionality need be provided by this routine. This greatly simplifies device drivers for devices that are supported by processor DMA. Physical drivers that are supported by peripheral DMA must provide this function, but should simply return ADI_DEV_NOT_SUPPORTED as this routine should never get called.

For devices that are not supported by peripheral DMA, the adi_pdd_Write function is passed one or more buffers that the application has provided for transmission out through the device. The physical driver can choose to process the buffers immediately, or provide the logic and functionality to queue or stage these buffers for transmission at a later time. The physical driver is required, however, to process the buffers in the order in which they were received.

Each buffer has a processed flag and processed size flag that the physical driver sets based on when it considers a buffer processed and how much data was transmitted out through the device. Unlike the adi_pdd_Read case, the entire contents of the buffer is expected to be transmitted.

Also, any buffer can be flagged by the application for notification when the buffer has completed processing. If a buffer is not flagged for a callback, the physical driver does not notify the device manager when the buffer is processed. However, if the buffer is flagged for a callback, once the buffer is processed the physical driver is obligated to set the processed flag and processed size field in the buffer and notify the device manager via the device manager's callback function that was passed to the physical driver as a parameter in the adi_pdd_Open function call, that the buffer has completed processing.

adi_pdd_Close Functional Description

The adi_pdd_Close function is called by the device manager in response to the application calling the adi_dev_Close function. Its purpose is to gracefully shutdown and idle the device. For all API functions, if error checking is enabled, the routine validates the physical driver handle is upon entry into the function. For detailed reference information, see "adi_pdd_Close Functional Description" on page 10-56.

After validating the driver handle, the adi_pdd_Close function terminates all data transmission and reception if it is not already stopped, as it is possible for the application to call the adi_dev_Close function while dataflow is enabled.

The function idles the device and leaves the device in a state such that it can be opened again, should the application reopen the device at a later time. All resources that were allocated in support of the device are released. For example, if an error interrupt was hooked during the adi_pdd_Open function, it is released as part of the adi_pdd_Close function.

Device Manager API Reference

This section provides the device manager API. The device manager API is defined in the `adi_dev.h` file.

Notation Conventions

The reference pages for the API functions use the following format:

Name – Name and purpose of the function

Description – Function specification

Prototype – Required header file and functional prototype

Arguments – Description of function arguments

Return Value – Description of function return values

adi_dev_Close

Description

This function closes a device. Dataflow is stopped if it has not already been stopped and the device is put back into an idled state. After calling `adi_dev_Close`, the only way to access the device again is to first open it with the `adi_dev_Open` function call.

Prototype

```
u32 adi_dev_Close(
                  ADI_DEV_DEVICE_HANDLE    DeviceHandle);
```

Arguments

`DeviceHandle`	Handle used to identify the device

Return Value

`ADI_DEV_RESULT_SUCCESS`	Device closed successfully.
`ADI_DEV_RESULT_BAD_DEVICE_HANDLE`	Device handle does not identify a valid device.
`ADI_DEV_RESULT_DMA_ERROR`	Error occurred while closing down DMA for the device.
`xxx`	Device-specific return code

adi_dev_Control

Description

This function sets or detects a configuration parameter for a device.

Prototype

```
u32 adi_dev_Control(
        ADI_DEV_DEVICE_HANDLE         DeviceHandle,
        u32                           Command,
        void                          *pArg
);
```

Arguments

DeviceHandle	Handle used to identify the device
Command	Command identifier
pArg	Address of command-specific parameter

Return Value

ADI_DEV_RESULT_SUCCESS	Function completed successfully.
ADI_DEV_RESULT_BAD_DEVICE_HANDLE	Device handle does not identify a valid device.
ADI_DEV_RESULT_DMA_ERROR	Error was reported while configuring the DMA manager.
ADI_DEV_RESULT_NOT_SUPPORTED	Command is not supported.
xxx	Device-specific return code

adi_dev_Init

Description

This function creates a device manager and initializes memory for the device manager. This function is typically called at initialization time.

Prototype

```
u32 adi_dev_Init(
        void                        *pMemory,
        size_t                      MemorySize,
        u32                         *pMaxDevices,
        ADI_DEV_MANAGER_HANDLE      *pManagerHandle,
        void                        *pEnterCriticalParam
);
```

Arguments

pMemory	Pointer to an area of static memory used by the device manager
MemorySize	Size, in bytes, of memory supplied for the device manager
*pMaxDevices	On return, this argument contains the number of simultaneously open devices that the device manager can support given the memory supplied.
*pManagerHandle	Pointer to memory location where the handle to the device manager is stored
*pEnterCriticalParam	Parameter that is passed to the function that protects critical areas of code

Return Value

ADI_DEV_RESULT_SUCCESS	Device manager was successfully initialized.
ADI_DEV_RESULT_NO_MEMORY	Insufficient memory has been supplied to device manager.

adi_dev_Open

Description

This function opens a device for use. Internal data structures are initialized, preliminary device control is established, and the device is reset and prepared for use.

Prototype

```
u32 adi_dev_Open(
        ADI_DEV_MANAGER_HANDLE        ManagerHandle,
        ADI_DEV_PDD_ENTRY_POINT       *pEntryPoint,
        u32                           DeviceNumber,
        void                          *ClientHandle,
        ADI_DEV_DEVICE_HANDLE         *pDeviceHandle,
        ADI_DEV_DIRECTION             Direction,
        ADI_DMA_MANAGER_HANDLE        DMAHandle,
        ADI_DCB_HANDLE                DCBHandle,
        ADI_DCB_CALLBACK_FN           ClientCallback
);
```

Arguments

Argument	Explanation
ManagerHandle	Handle to the device manager that controls the device
*pEntryPoint	Address of the physical driver's entry point
DeviceNumber	Number identifying which device is open. Device numbers begin with zero. For example, if there are four serial ports, they are numbered 0 through 3.
*ClientHandle	Identifier defined by the application. The device manager passes this value back to the client as an argument in the callback function.

Argument	Explanation
*pDeviceHandle	Pointer to an application-provided location where the device manager stores an identifier defined by the device manager. All subsequent communication initiated by the client to the device manager for this device includes this handle.
Direction	Data direction for the device: inbound, outbound or bidirectional. (See "ADI_DEV_DIRECTION" on page 10-67.)
DMAHandle	Handle to the DMA manager service that is used for this device (can be NULL if DMA is not used)
DCBHandle	Handle to the deferred callback service that is used for this device. If NULL, all callbacks will be live and not deferred.
ClientCallback	Address of the client's callback function

Return Value

ADI_DEV_RESULT_SUCCESS	Device was opened successfully.
ADI_DEV_RESULT_BAD_MANAGER_HANDLE	Device manager handle does not point to a device manager.
ADI_DEV_RESULT_NO_MEMORY	Insufficient memory is available to open the device.
ADI_DEV_RESULT_DEVICE_IN_USE	Device is already in use.
xxx	Device-specific return code

adi_dev_Read

Description

This function reads data from a device or queues reception buffers to a device.

Prototype

```
u32 adi_dev_Read(
        ADI_DEV_DEVICE_HANDLE        DeviceHandle,
        ADI_DEV_BUFFER_TYPE          BufferType,
        ADI_DEV_BUFFER               *pBuffer
);
```

Arguments

DeviceHandle	Handle used to identify the device
BufferType	Identifies type of buffer: one-dimensional, two-dimensional, or circular. (See "ADI_DEV_BUFFER_TYPE" on page 10-66.)
*pBuffer	Address of the buffer or first buffer in a chain of buffers. (See "ADI_DEV_BUFFER" on page 10-82.)

Return Value

ADI_DEV_RESULT_SUCCESS	Function completed successfully.
ADI_DEV_RESULT_BAD_DEVICE_HANDLE	Device handle does not identify a valid device.
ADI_DEV_RESULT_DMA_ERROR	Error was reported while configuring the DMA manager.
ADI_DEV_RESULT_DATAFLOW_UNDEFINED	Dataflow method has not yet been set.
xxx	Device-specific return code

adi_dev_Terminate

Description

This function frees up all memory used by the device manager, stops data flow, closes all open device drivers, and terminates the device manager.

Prototype

```
u32 adi_dev_Terminate(
        ADI_DEV_MANAGER_HANDLE        ManagerHandle
);
```

Arguments

ManagerHandle	Handle to the device manager

Return Value

This function returns ADI_DEV_RESULT_SUCCESS if successful; any other value indicates an error.

adi_dev_Write

Description

This function writes data to a device or queues transmission buffers to a device.

Prototype

```
u32 adi_dev_Write(
        ADI_DEV_DEVICE_HANDLE      DeviceHandle,
        ADI_DEV_BUFFER_TYPE        BufferType,
        ADI_DEV_BUFFER             *pBuffer
);
```

Arguments

DeviceHandle	Handle used to identify the device.
BufferType	Identifies type of buffer: one-dimensional, two-dimensional, or circular. (See "ADI_DEV_BUFFER_TYPE" on page 10-66.)
*pBuffer	Address of the buffer or first buffer in a chain of buffers. (See "ADI_DEV_BUFFER" on page 10-82.)

Return Value

ADI_DEV_RESULT_SUCCESS	Function completed successfully.
ADI_DEV_RESULT_BAD_DEVICE_HANDLE	Device handle does not identify a valid device.
ADI_DEV_RESULT_DMA_ERROR	Error was reported while configuring the DMA manager.
ADI_DEV_RESULT_DATAFLOW_UNDEFINED	Dataflow method has not yet been set.
xxx	Device-specific return code

Device Manager Public Data Types and Enumerations

This section defines public data structures and enumerations used by the device manager service.

ADI_DEV_BUFFER_TYPE

The ADI_DEV_BUFFER_TYPE enumeration is used to specify the type of buffer provided to the driver. The following table describes the values for the ADI_DEV_BUFFER_TYPE enumeration.

Table 10-1. ADI_DEV_BUFFER_TYPE

Name	Description
ADI_DEV_BUFFER_UNDEFINED	Undefined type
ADI_DEV_1D	One-dimensional buffer
ADI_DEV_2D	Two-dimensional buffer
ADI_DEV_CIRC	Circular buffer
ADI_DEV_SEQ_1D	Sequential one-dimensional buffer
ADI_DEV_SWITCH	Switch buffer
ADI_DEV_UPDATE_SWITCH	Buffer to chain with the existing switch buffer
ADI_DEV_BUFFER_SKIP	Skip this buffer and DMA channel (for multi-DMA devices)
ADI_DEV_BUFFER_TABLE	Table of buffers
ADI_DEV_BUFFER_END a	End of buffer array

ADI_DEV_MODE

The ADI_DEV_MODE enumeration is used to specify the dataflow method. The following table describes the values for the ADI_DEV_MODE enumeration.

Table 10-2. ADI_DEV_MODE

Name	Description
ADI_DEV_MODE_UNDEFINED	Undefined mode
ADI_DEV_MODE_CIRCULAR	Circular buffer
ADI_DEV_MODE_CHAINED	Chained buffer
ADI_DEV_MODE_CHAINED_LOOPBACK	Chained buffer with loopback
ADI_DEV_MODE_SEQ_CHAINED	Sequential chained buffer
ADI_DEV_MODE_SEQ_CHAINED_LOOPBACK	Sequential chained buffer with loopback

ADI_DEV_DIRECTION

The ADI_DEV_DIRECTION enumeration is used to specify the data direction. The following table describes the values for ADI_DEV_DIRECTION enumeration.

Table 10-3. ADI_DEV_DIRECTION

Name	Description
ADI_DEV_DIRECTION_UNDEFINED	Undefined direction
ADI_DEV_DIRECTION_INBOUND	Inbound direction (read)

Table 10-3. ADI_DEV_DIRECTION (Cont'd)

Name	Description
ADI_DEV_DIRECTION_OUTBOUND	Outbound direction (write)
ADI_DEV_DIRECTION_BIDIRECTIONAL	Both inbound and outbound (read and write)

CALLBACK EVENTS

The device manager header file lists enumerations for callback events which are extensible by the physical device driver (PDD).

The starting value for device manager specific enumerations is 0x40000000. This value is defined in the services.h file as ADI_DEV_ENUMERATION_START.

The following table lists enumeration values for callback events.

Table 10-4. Callback Events

Name	Description
ADI_DEV_EVENT_START	0x40000000 - starting point
ADI_DEV_EVENT_BUFFER_PROCESSED	0x0001 - buffer completed processing
ADI_DEV_EVENT_SUB_BUFFER_PROCESSED	0x0002 - a circular sub-buffer has been processed
ADI_DEV_EVENT_DMA_ERROR_INTERRUPT	0x0003 - DMA controller generated an error interrupt

RESULT CODES

The device manager header file adi_dev.h lists enumeration values for function return result codes, which are extensible by the physical device driver (PDD).

The starting value for device manager specific enumerations is 0x40000000. This value is defined in the file services.h as ADI_DEV_ENUMERATION_START.

The following table lists enumeration values for result codes.

Table 10-5. Result Codes

Name	Description
ADI_DEV_RESULT_SUCCESS	Generic success = 0
ADI_DEV_RESULT_FAILED	Generic failure = 1
ADI_DEV_RESULT_START	0x40000000 - starting point
ADI_DEV_RESULT_NOT_SUPPORTED	Functionality is not supported
ADI_DEV_RESULT_DEVICE_IN_USE	Device already in use
ADI_DEV_RESULT_NO_MEMORY	Insufficient memory for operation
ADI_DEV_RESULT_NOT_USED_1	No longer used
ADI_DEV_RESULT_BAD_DEVICE_NUMBER	Bad device number
ADI_DEV_RESULT_DIRECTION_NOT_SUPPORTED	Data direction not supported
ADI_DEV_RESULT_BAD_DEVICE_HANDLE	Bad device handle
ADI_DEV_RESULT_BAD_MANAGER_HANDLE	Bad device manager handle
ADI_DEV_RESULT_BAD_PDD_HANDLE	Bad physical driver handle

Table 10-5. Result Codes (Cont'd)

Name	Description
ADI_DEV_RESULT_INVALID_SEQUENCE	Invalid sequence of commands
ADI_DEV_RESULT_ATTEMPTED_READ_ON_OUTBOUND_DEVICE	Attempted read on outbound device
ADI_DEV_RESULT_ATTEMPTED_WRITE_ON_INBOUND_DEVICE	Attempted write on inbound device
ADI_DEV_RESULT_DATAFLOW_UNDEFINED	Dataflow method is undefined
ADI_DEV_RESULT_DATAFLOW_INCOMPATIBLE	Operation incompatible with the dataflow method
ADI_DEV_RESULT_BUFFER_TYPE_INCOMPATIBLE	Device does not support the given buffer type
ADI_DEV_RESULT_NOT_USED_2	No longer used
ADI_DEV_RESULT_CANT_HOOK_INTERRUPT	Cannot hook the interrupt
ADI_DEV_RESULT_CANT_UNHOOK_INTERRUPT	Cannot unhook the interrupt
ADI_DEV_RESULT_NON_TERMINATED_LIST	Non-NULL terminated buffer list
ADI_DEV_RESULT_NO_CALLBACK_FUNCTION_SUPPLIED	No callback function provided to Open function
ADI_DEV_RESULT_REQUIRES_UNIDIRECTIONAL_DEVICE	Requires unidirectional device
ADI_DEV_RESULT_REQUIRES_BIDIRECTIONAL_DEVICE	Requires bidirectional device
ADI_DEV_RESULT_TWI_LOCKED	TWI locked in other operation
ADI_DEV_RESULT_REQUIRES_TWI_CONFIG_TABLE	Requires configuration table for the TWI driver
ADI_DEV_RESULT_CMD_NOT_SUPPORTED	Command not supported

Table 10-5. Result Codes (Cont'd)

Name	Description
ADI_DEV_RESULT_INVALID_REG_ADDRESS	Accessing invalid device register address
ADI_DEV_RESULT_INVALID_REG_FIELD	Accessing invalid device register field location
ADI_DEV_RESULT_INVALID_REG_FIELD_DATA	Providing invalid device register field value
ADI_DEV_RESULT_ATTEMPT_TO_WRITE_READONLY_REG	Attempt to write a read-only register
ADI_DEV_RESULT_ATTEMPT_TO_ACCESS_RESERVE_AREA	Attempt to access a reserved location
ADI_DEV_RESULT_ACCESS_TYPE_NOT_SUPPORTED	Access type provided by the driver is not supported
ADI_DEV_RESULT_DATAFLOW_NOT_ENABLED	Sync mode- enable dataflow before providing buffers
ADI_DEV_RESULT_BAD_DIRECTION_FIELD	Sequential I/O mode- buffers provided with invalid direction
ADI_DEV_RESULT_BAD_IVG	Bad IVG number detected
ADI_DEV_RESULT_SWITCH_BUFFER_PAIR_INVALID	Invalid buffer pair provided with switch/update switch buffer type
ADI_DEV_RESULT_DMA_CHANNEL_UNAVAILABLE	No DMA channel available to process command/buffer
ADI_DEV_RESULT_ATTEMPTED_BUFFER_TABLE_NESTING	Buffer table nesting is not allowed

COMMAND IDs

The device manager header file `adi_dev.h` lists enumeration values for command IDs, which are extensible by the physical device driver (PDD).

The starting value for device manager specific enumerations is 0x40000000. This value is defined in the file `services.h` as `ADI_DEV_ENUMERATION_START`.

The following table lists enumeration values for Command IDs.

Table 10-6. Command IDs

Name	Description	Value
ADI_DEV_CMD_START	ADI_DEV_ENUMERATION_START	0x40000000
ADI_DEV_CMD_UNDEFINED	Undefined	
ADI_DEV_CMD_END	End of table	NULL
ADI_DEV_CMD_PAIR	Single command pair being passed	ADI_DEV_CMD_VALUE_PAIR
ADI_DEV_CMD_TABLE	Table of command pairs	ADI_DEV_CMD_VALUE_PAIR
ADI_DEV_CMD_SET_DATAFLOW	Enable/disable dataflow	TRUE/FALSE
ADI_DEV_CMD_SET_DATAFLOW_METHOD	Set dataflow method	TRUE/FALSE
ADI_DEV_CMD_NOT_USED_1	No longer used	
ADI_DEV_CMD_SET_SYNCHRONOUS	Set device to synchronous I/O	TRUE/FALSE
ADI_DEV_CMD_NOT_USED_2	No longer used	

Table 10-6. Command IDs (Cont'd)

Name	Description	Value
ADI_DEV_CMD_SET_STREAMING	Set streaming mode	TRUE/FALSE
ADI_DEV_CMD_GET_MAX_INBOUND_SIZE	Get size of biggest inbound packet	u32*
ADI_DEV_CMD_GET_MAX_OUTBOUND_SIZE	Get size of biggest outbound packet	u32*
ADI_DEV_CMD_GET_PERIPHERAL_DMA_SUPPORT	Query whether device supports processor DMA	u32*
ADI_DEV_CMD_GET_INBOUND_DMA_PMAP_ID	Get peripheral's DMA PMAP value for inbound data	ADI_DMA_PMAP*
ADI_DEV_CMD_GET_OUTBOUND_DMA_PMAP_ID	Get peripheral's DMA PMAP value for outbound data	ADI_DMA_PMAP*
ADI_DEV_CMD_SET_INBOUND_DMA_CHANNEL_ID	Set DMA channel ID for inbound DMA	ADI_DMA_CHANNEL_ID
ADI_DEV_CMD_GET_INBOUND_DMA_CHANNEL_ID	Get DMA channel ID for inbound DMA	ADI_DMA_CHANNEL_ID*
ADI_DEV_CMD_SET_OUTBOUND_DMA_CHANNEL_ID	Set DMA channel ID for outbound DMA	ADI_DMA_CHANNEL_ID
ADI_DEV_CMD_GET_OUTBOUND_DMA_CHANNEL_ID	Get DMA channel ID for outbound DMA	ADI_DMA_CHANNEL_ID*
ADI_DEV_CMD_GET_2D_SUPPORT	Query whether device supports 2D transfers	u32*
ADI_DEV_CMD_SET_ERROR_REPORTING	Enable/disable error reporting	TRUE/FALSE
ADI_DEV_CMD_FREQUENCY_CHANGE_PROLOG	Notification of impending core/system frequency change	ADI_DEV_FREQUENCIES*

Table 10-6. Command IDs (Cont'd)

Name	Description	Value
ADI_DEV_CMD_FREQUENCY_CHANGE_EPILOG	Notification of new core/system frequency settings	ADI_DEV_FREQUENCIES*
ADI_DEV_CMD_REGISTER_READ	Read a single device register	ADI_DEV_ACCESS_REGISTER*
ADI_DEV_CMD_REGISTER_FIELD_READ	Read a specific device register field	ADI_DEV_ACCESS_REGISTER_FIELD *
ADI_DEV_CMD_REGISTER_TABLE_READ	Read a table of selective device registers	ADI_DEV_ACCESS_REGISTER*
ADI_DEV_CMD_REGISTER_FIELD_TABLE_READ	Read table of selective device register(s) field(s)	ADI_DEV_ACCESS_REGISTER_FIELD*
ADI_DEV_CMD_REGISTER_BLOCK_READ	Read a block of consecutive device registers	ADI_DEV_ACCESS_REGISTER_BLOCK*
ADI_DEV_CMD_REGISTER_WRITE	Write to a single device register	ADI_DEV_ACCESS_REGISTER*
ADI_DEV_CMD_REGISTER_FIELD_WRITE	Write to a specific device register field	ADI_DEV_ACCESS_REGISTER_FIELD*
ADI_DEV_CMD_REGISTER_TABLE_WRITE	Write to a table of selective device registers	ADI_DEV_ACCESS_REGISTER
ADI_DEV_CMD_REGISTER_FIELD_TABLE_WRITE	Write to a table of selective device register(s) field(s)	ADI_DEV_ACCESS_REGISTER_FIELD*
ADI_DEV_CMD_REGISTER_BLOCK_WRITE	Write to a block of consecutive device registers	ADI_DEV_ACCESS_REGISTER_BLOCK*
ADI_DEV_CMD_UPDATE_1D_DATA_POINTER	Update the data pointer in a single 1D buffer	ADI_DEV_1D_BUFFER*
ADI_DEV_CMD_UPDATE_2D_DATA_POINTER	Update the data pointer in a single 2D buffer	ADI_DEV_2D_BUFFER*

Table 10-6. Command IDs (Cont'd)

Name	Description	Value
ADI_DEV_CMD_UPDATE_SEQ_1D_DATA_POINTER	Update the data pointer in a single sequential 1D buffer	ADI_DEV_SEQ_1D_BUFFER*
ADI_DEV_CMD_GET_INBOUND_DMA_CURRENT_ADDRESS	Get current address register value of inbound DMA	u32*
ADI_DEV_CMD_GET_OUTBOUND_DMA_CURRENT_ADDRESS	Get current address register value of outbound DMA	u32*

ADI_DEV_1D_BUFFER

The data structure ADI_DEV_1D_BUFFER describes a normal one-dimensional buffer. The following table describes the elements of this data structure.

Table 10-7. ADI_DEV_1D_BUFFER

Name	Type	Description
Reserved	char[ADI_DEV_RESERVED_SIZE]	Reserved for physical device driver use
Data	void*	Pointer to data
ElementCount	u32	Data element count
ElementWidth	u32	Data element width (in bytes)
CallbackParameter	void*	Callback flag/pArg value
ProcessedFlag	volatile u32	Processed flag
ProcessedElementCount	u32	Number of bytes processed

Table 10-7. ADI_DEV_1D_BUFFER (Cont'd)

Name	Type	Description
pNext	struct adi_dev_1d_buffer*	Next buffer
pAdditionalInfo	void*	Device-specific pointer to additional information

ADI_DEV_2D_BUFFER

The data structure ADI_DEV_2D_BUFFER describes a normal one-dimensional buffer. The following table describes the elements of this data structure.

Table 10-8. ADI_DEV_2D_BUFFER

Name	Type	Description
Reserved	char[ADI_DEV_RESERVED_SIZE]	Reserved for physical device driver use
Data	void*	Pointer to data
ElementWidth	u32	Data element width (in bytes)
XCount	u32	XCOUNT value for 2D
XModify	s32	XMODIFY value for 2D
YCount	u32	YCOUNT value for 2D
YModify	s32	YMODIFY value for 2D
CallbackParameter	void*	Callback flag/pArg value
ProcessedFlag	volatile u32	Processed flag
ProcessedElementCount	u32	Number of bytes processed

Table 10-8. ADI_DEV_2D_BUFFER (Cont'd)

Name	Type	Description
pNext	struct adi_dev_2d_buffer*	Next buffer
pAdditionalInfo	void*	Device-specific pointer to additional information

ADI_DEV_CIRCULAR_BUFFER

The data structure ADI_DEV_CIRCULAR_BUFFER describes a normal circular buffer. The following table describes the elements of this room with data structure.

Table 10-9. ADI_DEV_CIRCULAR_BUFFER

Name	Type	Description
Reserved	char[ADI_DEV_RESERVED_SIZE]	Reserved for physical device driver use
Data	void*	Pointer to data
SubBufferCount	u32	Number of sub-buffers
SubBufferElementCount	u32	Number of data elements in one sub-buffer
ElementWidth	u32	Data element width (in bytes)
CallbackType	ADI_DEV_CIRCULAR_CALLBACK	Circular buffer callback switch
pAdditionalInfo	void*	Device-specific pointer to additional information

ADI_DEV_SEQ_1D_BUFFER

The data structure ADI_DEV_SEQ_1D_BUFFER describes a sequential one-dimensional buffer. The following table describes the elements of this data structure.

Table 10-10. ADI_DEV_SEQ_1D_BUFFER

Name	Type	Description
BufferType	ADI_DEV_BUFFER_TYPE	Buffer type
pDirection	union ADI_DEV_BUFFER	Pointer to a buffer of above type

ADI_DEV_BUFFER_PAIR

The data structure ADI_DEV_BUFFER_PAIR describes a sequential one-dimensional buffer. The following table describes the elements of this data structure.

Table 10-11. ADI_DEV_BUFFER_PAIR

Name	Type	Description
Buffer	ADI_DEV_1D_BUFFER	Buffer
Direction	ADI_DEV_DIRECTION	Direction

ADI_DEV_DMA_INFO

The data structure ADI_DEV_DMA_INFO holds peripheral DMA channel information. The following table describes the elements of this data structure.

Table 10-12. ADI_DEV_DMA_INFO

Name	Type	Description
MappingID	ADI_DMA_PMAP	DMA peripheral mapping ID
ChannelHandle	ADI_DMA_CHANNEL_HANDLE	Handle to this DMA channel
SwitchModeFlag	u8	Switch mode status flag (TRUE when in switch mode)
pSwitchHead	ADI_DMA_DESCRIPTOR_UNION*	Head of switch buffer chain
pSwitchTail	ADI_DMA_DESCRIPTOR_UNION*	Tale of switch buffer chain
pNext	struct ADI_DEV_DMA_INFO*	Pointer to structure holding next DMA channel information

ADI_DEV_DMA_ACCESS

The data structure ADI_DEV_DMA_ACCESS accesses a peripheral's inbound and outbound DMA chain data. The following table describes the elements of this data structure.

Table 10-13. ADI_DEV_DMA_ACCESS

Name	Type	Description
DmaChannelCount	u8	Number of DMA channels to access and selected device
pData	void*	Start location of an array for the DMA-related data

ADI_DEV_FREQUENCIES

The data structure `ADI_DEV_FREQUENCIES` maintains information about the clock frequency changes. The following table describes the elements of this data structure.

Table 10-14. ADI_DEV_FREQUENCIES

Name	Type	Description
`CoreClock`	`u32`	Core clock (`CCLK`)
`SystemClock`	`u32`	System clock (`SCLK`)

ADI_DEV_ACCESS_REGISTER

The data type `ADI_DEV_ACCESS_REGISTER` is for accessing a single, off-chip device register. The following table describes the elements of this data structure.

Table 10-15. ADI_DEV_ACCESS_REGISTER

Name	Type	Description
`Address`	`u16`	Device register address
`Data`	`u16`	Data to be written to, or read from the register

ADI_DEV_ACCESS_REGISTER_BLOCK

The data type `ADI_DEV_ACCESS_REGISTER_BLOCK` is for accessing blocks of consecutive, off-chip device registers. The following table describes the elements of this data structure.

Table 10-16. ADI_DEV_ACCESS_REGISTER_BLOCK

Name	Type	Description
`Count`	`u32`	Number of registers to be accessed
`Address`	`u16`	Starting address of register block
`pData`	`u16*`	Pointer to an array of register data to be written to, or read from the register block

ADI_DEV_ACCESS_REGISTER_FIELD

The data type `ADI_DEV_ACCESS_REGISTER_FIELD` is for accessing fields within off-chip device registers. The following table describes the elements of this data structure.

Table 10-17. ADI_DEV_ACCESS_REGISTER_FIELD

Name	Type	Description
`Address`	`u16`	Address of register to be accessed
`Field`	`u16`	Register field to be accessed (see off-chip driver header file)
`Data`	`u16`	Data to be written to, or read from the register field

ADI_DEV_BUFFER

The union ADI_DEV_BUFFER describes a union of all the buffer types. The following table describes the elements of this union.

Table 10-18. ADI_DEV_BUFFER

Name	Type	Description
OneD	ADI_DEV_1D_BUFFER	One-dimensional buffer
TwoD	ADI_DEV_2D_BUFFER	Two-dimensional buffer
Circular	ADI_DEV_CIRCULAR_BUFFER	Circular buffer
Seq1D	ADI_DEV_SEQ_1D_BUFFER	One-dimensional sequential buffer
BufferPair	ADI_DEV_BUFFER_PAIR	Buffer pair

Physical Driver API Reference

This section describes the API used between the device manager and each physical driver. The physical driver API is defined in the `adi_dev.h` file.

Notation Conventions

The reference pages for the API functions use the following format:

Name – Name and purpose of the function

Description – Function specification

Prototype – Required header file and functional prototype

Arguments – Description of function arguments

Return Value – Description of function return values

adi_pdd_Close

Description

This function closes a device. Dataflow is stopped if it has not already been stopped and the device is put back into an idle state.

Prototype

```
u32 adi_pdd_Close(
                  ADI_PDD_DEVICE_HANDLE   PDDHandle
);
```

Arguments

PDDHandle	Handle used to identify the device

Return Value

ADI_DEV_RESULT_SUCCESS	Device closed successfully.
xxx	Device-specific code

adi_pdd_Control

Description

This function sets or detects a configuration parameter for a device.

Prototype

```
u32 adi_pdd_Control(
        ADI_DEV_PDD_HANDLE          PDDHandle,
        u32                         Command,
        void                        *pArg
);
```

Arguments

PDDHandle	Handle used to identify the device
Command	Command identifier
pArg	Address of command-specific parameter

Return Value

ADI_DEV_RESULT_SUCCESS	Function completed successfully.
ADI_DEV_RESULT_NOT_SUPPORTED	Command is not supported.
xxx	Device-specific return code

adi_pdd_Open

Description

This function opens a physical device for use. Internal data structures are initialized, preliminary device control is established, and the device is reset and prepared for use.

Prototype

```
u32 adi_ppd_Open(
        ADI_DEV_MANAGER_HANDLE       ManagerHandle,
        u32                          DeviceNumber,
        ADI_DEV_DEVICE_HANDLE        DeviceHandle,
        ADI_DEV_PDD_HANDLE           *pPDDHandle,
        ADI_DEV_DIRECTION            Direction,
        void                         *pEnterCriticalParam,
        ADI_DMA_MANAGER_HANDLE       DMAHandle,
        ADI_DCB_HANDLE               DCBHandle,
        ADI_DCB_CALLBACK_FN          DMCallback
);
```

Arguments

Argument	Explanation
ManagerHandle	Handle to the device manager that controls the physical driver
DeviceNumber	Number identifying which device is open. Device numbers begin with zero. For example, if there are four serial ports, they are numbered 0 through 3.
DeviceHandle	Device manager-supplied parameter that uniquely identifies the device to the device manager
*pPDDHandle	Pointer to a location where the physical driver stores a handle that uniquely identifies the device to the physical driver

Argument	Explanation
Direction	Data direction for the device: inbound, outbound, or bidirectional
*pEnterCriticalParam	Parameter that is passed to the function that protects critical areas of code.
DMAHandle	Handle to the DMA manager service that is used for this device (can be NULL if DMA is not used)
DCBHandle	Handle to the deferred callback service that is used for this device. If NULL, all callbacks are live and not deferred.
DMCallback	Address of the device manager's callback function

Return Value

ADI_DEV_RESULT_SUCCESS	Device opened successfully.
ADI_DEV_RESULT_DEVICE_IN_USE	Device manager handle does not point to a device manager.
xxx	Device-specific return code

adi_pdd_Read

Description

This function provides buffers to a device for reception of inbound data. This function is never called for devices that are supported by peripheral DMA.

Prototype

```
u32 adi_pdd_Read(
        ADI_DEV_PDD_HANDLE          PDDHandle,
        ADI_DEV_BUFFER_TYPE         BufferType,
        ADI_DEV_BUFFER              *pBuffer
);
```

Arguments

PDDHandle	Handle used to identify the device
BufferType	Identifies type of buffer: one-dimensional, two-dimensional or circular
*pBuffer	Address of the buffer or first buffer in a chain of buffers

Return Value

ADI_DEV_RESULT_SUCCESS	Function completed successfully.
ADI_DEV_RESULT_BAD_PDD_HANDLE	PDD handle does not identify a valid device.
xxx	Device-specific return code

adi_pdd_Write

Description

This function provides buffers to a device for transmission of outbound data. This function is never called for devices that are supported by peripheral DMA.

Prototype

```
u32 adi_pdd_Write(
        ADI_DEV_PDD_HANDLE         PDDHandle,
        ADI_DEV_BUFFER_TYPE        BufferType,
        ADI_DEV_BUFFER             *pBuffer
);
```

Arguments

PDDHandle	Handle used to identify the device
BufferType	Identifies type of buffer: one-dimensional, two-dimensional, or circular
*pBuffer	Address of the buffer or first buffer in a chain of buffers

Return Value

ADI_DEV_RESULT_SUCCESS	Function completed successfully.
ADI_DEV_RESULT_BAD_PDD_HANDLE	PDD handle does not identify a valid device.
xxx	Device-specific return code

Examples

Examples showing how to use the device driver model as well as Analog Devices device drivers are provided with the device driver and system services distribution media.

For examples of applications using the device drivers, see the `Blackfin/EZ-Kits` directory. Source code for all Analog Devices-provided device drivers is located in the `Blackfin/Lib/Src/Driver` directory.

11 REAL-TIME CLOCK SERVICE

This chapter describes how to use the real-time clock service within the system services library to enable the features of the real-time clock on Blackfin processors. The application programming interface (API) described in this chapter allows real-time clock events to be scheduled and serviced in a manner consistent with the other system services.

This chapter contains the fo llowing sections:

Introduction

The real-time clock service provides an easy-to-use interface to the real-time clock that is available on most Blackfin processors. In addition to the reading and writing of the date and time, the service allows an application to coordinate eight different real-time clock events in a consistent manner, regardless of the processor derivative. There are five periodic events that can be enabled to occur each second, each minute, each hour, each day at midnight, and each day at a specific time. There is an alarm that occurs once at a specific date and time. There is a stopwatch event that occurs when a given duration has elapsed. And there is an event which signals the completion of all pending register writes.

The sections in this chapter cover the basic operation of the real-time clock service, describing the application programming interface (API) and providing the necessary instructions for initializing and using the real-time clock service in a client application.

The debug version of the system services library provides parameter checking for a more complete test of the API function parameters and other error conditions. Analog Devices strongly recommends that development work be done using the debug versions of the system services library, and that final test and deployment be done with the release version of the library.

Operation

This section describes the overall operation of the real-time clock service. Details on the application programming interface (API) can be found later in this chapter.

Initialization

Prior to using the real-time clock service, the application must initialize the service by calling the initialization function, `adi_rtc_Init()`. Unlike some system services which require the application to provide memory to the service upon initialization, the real-time clock service requires no additional memory. The only parameter passed to `adi_rtc_Init()` is a critical region parameter that may be used later if the interrupt manager is called upon to protect critical regions of code. In the current implementation of the system services, a NULL pointer is used for the critical region parameter. For more information, refer to "Protecting Critical Code Regions" on page 2-12.

Before initializing the real-time clock service, the application should initialize the interrupt manager by calling `adi_int_Init()`. If callbacks are to be deferred, rather than "live", then the deferred callback (DCB) manager should also be initialized by calling `adi_dcb_Init()`.

Some of the real-time clock hardware memory-mapped registers (MMR) have certain limitations, in that they allow only one value to be written in any given 1 Hz cycle. A value written to the MMR does not take effect until the next 1 Hz tick, and any subsequent value written to the same register within that time period is discarded. The real-time clock service implements a register caching system that works around this issue, to ensure that none of the intended functionality is lost. The application should not attempt to access any of the memory-mapped registers directly, but should depend solely upon the API functions provided by the service.

When the application calls `adi_rtc_Init()`, the register caches are cleared. The prescaler bit is set so the real-time clock runs in 1 Hz mode, like a regular clock. The callback environment is initialized and the event flag register is cleared of any pending events. The real-time clock interrupt handler is hooked into the IVG chain, and the real-time clock service is ready to go. Real-time clock interrupts are initialized to also "wake up" the processor. If this is not the desired behavior, the application may call the API function `adi_rtc_DisableWakeup()`.

Termination

When the application no longer requires the real-time clock service, it calls the termination function, `adi_rtc_Terminate()`. This function removes any callbacks that were installed, cleaning up all statically-defined data structures.

Setting and Reading the Date and Time

To set the date and time of the real-time clock, the real-time clock service provides an API function called `adi_rtc_SetDateTime()`. To use this function, the application declares a structure of type `tm`, which is a C-standard time structure defined in the system include file, `time.h`. The application sets the fields of this structure with the month, day, year, hour, minute, and second and passes a pointer to the structure to `adi_rtc_SetDateTime()`. The function converts the data to 32-bit integer format and loads it into the `RTC_STAT` register, where the real-time clock hardware maintains the date and time. The `RTC_STAT` register is shown below. Each field of the `tm` structure is represented by a range of bits within the register.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Day Counter (0–32767)															Hour (cont'd)

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Hour (0–23)				Minutes (0–59)						Seconds (0–59)					

The `adi_rtc_SetDateTime()` function only needs to be called once, although it can be called multiple times. The date and time take effect on the next 1 Hz tick and are maintained in one-second increments for as long as the external battery power source is present. An application may subsequently call upon the real-time clock service to obtain the current date and time, or to install callbacks for the clock-driven events.

The real-time clock service provides an API function called `adi_rtc_GetDateTime()` which allows the application to retrieve the date and time from the memory-mapped `RTC_STAT` register. To use this function, the application declares a structure of type `tm`, which is a C-standard time structure defined in the system include file, `time.h`. The application passes a pointer to the `tm` structure. The function reads the date and time from the `RTC_STAT` register and returns the information in the `tm` structure.

The real-time clock service supports only the functionality of the hardware. It does not make adjustments to the date and time for daylight savings or time zones. The application can make these adjustments easily since the date and time are stored in a `tm` structure for compatibility with standard time functions found in the VisualDSP C/C++ Compiler Run-Time Library.

Real-Time Clock Events

The real-time clock service provides a mechanism for allowing certain predefined conditions, referred to as *events*, to be serviced at the interrupt level during regular program execution. Each event is identified by a unique `Event ID` that is defined in the include file, `adi_rtc.h`. The application provides a callback function to handle an event. The real-time clock service provides the mechanism for installing and removing callbacks, and for invoking a callback when the appropriate conditions are met. The real-time clock service supports eight different events. The application enables an event by calling the `adi_rtc_InstallCallback()` function, passing the appropriate `Event ID`.

One Second Periodic Event

The application may enable an interrupt to occur when the *seconds* counter in the `RTC_STAT` register advances. This interrupting event becomes enabled when the application calls the `adi_rtc_InstallCallback()` function, passing the argument `ADI_RTC_EVENT_SECONDS`. This event stays enabled and periodic interrupts continue to occur every second, until the application disables the event, by passing the argument `ADI_RTC_EVENT_SECONDS` to the `adi_rtc_RemoveCallback()` function.

One Minute Periodic Event

The application may enable a periodic interrupt to occur when the *minutes* counter of the RTC_STAT register advances. This interrupting event becomes enabled when the application calls the adi_rtc_InstallCallback() function, passing the argument ADI_RTC_EVENT_MINUTES. This event stays enabled and periodic interrupts continue to occur every minute, until the application disables the event by passing the argument ADI_RTC_EVENT_MINUTES to the adi_rtc_RemoveCallback() function.

Hourly Periodic Event

The application may enable a periodic interrupt to occur when the *hours* counter of the RTC_STAT register advances. This interrupting event becomes enabled when the application calls the adi_rtc_InstallCallback() function, passing the argument ADI_RTC_EVENT_HOURS. This event stays enabled and periodic interrupts continue to occur every hour until the application disables the event by passing the argument ADI_RTC_EVENT_HOURS to the adi_rtc_RemoveCallback() function.

Daily Periodic Event

The application may enable a periodic interrupt to occur at midnight when the *days* counter of the RTC_STAT register advances. This interrupting event becomes enabled when the application calls the adi_rtc_InstallCallback() function, passing the argument ADI_RTC_EVENT_DAYS. This event stays enabled and periodic interrupts continue to occur each day until the application disables the event by passing the argument ADI_RTC_EVENT_DAYS to the adi_rtc_RemoveCallback() function.

Periodic or One-Shot Stopwatch Event

The application may set up a *stopwatch* event to interrupt when a specified time duration has elapsed. The same stopwatch event can be either periodic or one shot. The event becomes enabled when the application passes the argument `ADI_RTC_EVENT_STOPWATCH` to the `adi_rtc_InstallCallback()` function, also passing the number of seconds of the stopwatch time duration. The stopwatch event occurs only once by default, as a "one-shot" stopwatch event. The callback function may then either disable the event by passing the argument `ADI_RTC_EVENT_STOPWATCH` to the `adi_rtc_RemoveCallback()` function, or it may re-enable the stopwatch event by calling the API function `adi_rtc_ResetStopwatch()`. If re-enabled, the stopwatch becomes a periodic event.

Once Only Alarm Event

The application may enable an alarm event that interrupts *once* on a given day at a specific time. This interrupting event becomes enabled when the application passes the argument `ADI_RTC_EVENT_ONCE_ALM` to the `adi_rtc_InstallCallback()` function, also passing a `tm` structure containing the date and time of the alarm. After the alarm event occurs, the callback may be removed by passing the argument `ADI_RTC_EVENT_ONCE_ALM` to the `adi_rtc_RemoveCallback()` function. Then, another such event can be scheduled by installing the callback again. After this event has been scheduled, and before it occurs, it may be canceled by removing the callback.

Each Day Alarm Event

The application may enable an alarm that interrupts at a specific time *each day* as long as the alarm is enabled. This interrupting event becomes enabled when the application passes the argument `ADI_RTC_EVENT_EACH_DAY_ALM` to the `adi_rtc_InstallCallback()` function, also passing a `tm` structure containing the time of day that the alarm should occur. The event stays enabled and the interrupt occurs each day at the specified time, until the application disables the event by calling the `adi_rtc_RemoveCallback()` function, passing the argument `ADI_RTC_EVENT_EACH_DAY_ALM`.

Pending Writes Complete Event

All *writes* to the memory-mapped registers `RTC_STAT`, `RTC_ALARM`, `RTC_SWCNT`, and `RTC_ICTL` are synchronized to the 1 Hz tick. The application may want to be alerted when the pending writes have completed. The application may enable an interrupt to occur when all pending writes to these registers have completed. This event becomes enabled when the application passes the argument `ADI_RTC_EVENT_WRITES_COMPLETE` to the `adi_rtc_InstallCallback()` function. The event stays enabled until the application disables the event by calling the `adi_rtc_RemoveCallback()` function, passing the argument `ADI_RTC_EVENT_WRITES_COMPLETE`.

Callbacks

The application may enable and process any of the real-time clock events by defining and installing a *callback* for that event. A callback is simply a function, associated with a specific event, or a group of events, that is executed whenever the associated event occurs. A separate callback function may be written for each event, or a single callback function may handle all the real-time clock events, perhaps within a case statement. Unless a callback is deferred, it is executed from within the interrupt service routine, by the real-time clock interrupt handler. The handler, part of the real-time clock service, is called from the interrupt manager whenever a real-time clock interrupt is triggered by one of the eight possible real-time clock events. The real-time clock service provides the function to install callbacks, the function to remove callbacks, and the interrupt handler which invokes the callbacks. The application provides the callback function, which controls how each event is processed, and also an optional data structure, comprised of event-specific information, that is passed to the callback function from the real-time clock service interrupt handler. A coding example appears later in this section which demonstrates how that data structure can be used.

The Callback List

To process callbacks, the real-time clock maintains a table with an entry for each of the eight events. Each entry contains a pointer to a callback function, or to NULL if no callback has been installed. When the application calls `adi_rtc_InstallCallback` passing an `Event ID`, the real-time clock service inserts a pointer to the callback function into the entry for the event. When the event occurs, the real-time clock interrupt handler uses the entry to find and execute the callback function designated for this event. When the application calls `adi_rtc_RemoveCallback` to disable an event, the callback pointer is removed from the callback list entry for that event.

Installing a Callback

To install callback functionality for one of the real-time clock events, the application simply calls the API function `adi_rtc_InstallCallback` passing the `Event ID`. For some events, such as alarms and stopwatch events, other information is passed to this function, such as the time that the alarm should occur, or the duration of a stopwatch period. The `adi_rtc_InstallCallback` function uses this information to configure the hardware registers to generate the interrupt at the appropriate time. An optional data structure called `ClientHandle` is also passed to the `adi_rtc_InstallCallback` function, containing information to be stored in the callback list and passed to the callback when it occurs.

Removing a Callback

The application may disable the processing of an event by passing the Event ID as a parameter to the function adi_rtc_RemoveCallback. This function removes the callback from the callback list entry for the event, and also configures the hardware so it no longer generates an interrupt for the event.

The Real-Time Clock Service Interrupt Handler

The real-time clock service has an interrupt handler that is "hooked" into the interrupt manager's "chain" for the associated interrupt vector group (IVG). Note the difference between the interrupt handler, which is defined in the real-time clock service to process real-time clock events, and theinterrupt service routine (ISR), which is defined in the interrupt manager to handle any interrupting event of a given IVG level. The interrupt manager's ISR executes the real-time clock interrupt handler when a real-time clock interrupting event occurs. The real-time clock interrupt handler reads the event flags in the RTC_ISTAT register to determine which event triggered the interrupt. The handler then looks at the callback list entry for the event (see "The Callback List " on page 11-9). The entry will point to the callback function (see "Callbacks" on page 11-8) and to the ClientHandle parameter (see "Using the ClientHandle Parameter in a Callback" on page 11-10). The handler executes the callback, passing the ClientHandle parameter. When the callback is complete, it returns to the real-time clock interrupt handler, which returns control to the interrupt manager.

Using the ClientHandle Parameter in a Callback

An optional data structure called ClientHandle is also passed as an argument to the adi_rtc_InstallCallback function. This user-defined structure contains event-specific information to be stored in the callback list entry. When the event occurs, the interrupt manager executes the real-time clock service interrupt handler. The interrupt handler uses the callback list to find the address of the callback and the ClientHandle information that it must pass to the callback.

Coding Example

A PeriodicStopwatch example is installed with VisualDSP++ 5.0. This example demonstrates the use of the functions adi_rtc_InstallCallback and adi_rtc_RemoveCallback for setting up a stopwatch event and servicing it within a callback. It demonstrates the use of the adi_rtc_ResetStopwatch function to re-enable the stopwatch event, and the use of the ClientHandle to creatively control event handling, so that a periodic stopwatch event occurs repeatedly every five seconds for twenty seconds, and then stops.

In the following code examaple, a data structure is defined, called STOPWATCH_INFO, which has three fields of information that are passed to the callback. The first field indicates that this event is periodic. The second field indicates the number of seconds that the callback function uses when it re-enables the stopwatch event, in this case, five. The third field tells the callback how many times to re-enable the stopwatch event, in this case, three. If this field is set to 0, the event recurs continuously. The ClientHandle argument is used to pass this data structure to the adi_rtc_InstallCallback function.

```
typedef struct
{
  u32 PeriodicFlag;    /* whether the callback shall be periodic
     or one-shot */
  u32 SecondsCounter;  /* value to place in the stopwatch
     count register when re-enabling the stopwatch */
  u32 NumRepetitions;  /* how many times to re-enable the
     stopwatch */
```

```
  u32 NumRepetitions;  /* how many times to re-enable the
    stopwatch */
} STOPWATCH_INFO;
```

In the example, a callback function is provided called `RTCCallback` which handles all the real-time clock events. (Only the processing of the `STOPWATCH` event is shown here.) The callback function accepts three arguments:

```
void   *ClientHandle

u32    EventID

void   *pArg
```

The `ClientHandle` contains the structure that was passed as a parameter to the `adi_rtc_InstallCallback` function when the callback was installed. The interrupt handler passes this argument to the callback function when the interrupt occurs. The `EventID` specifies which of the eight possible events generated the callback, in this case, the stopwatch event. The `pArg` is a flexible argument, defined as type `void*` and reserved for the service to pass any pertinent information the callback needs to process the event. The callback performs a switch on the `EventID` and executes a case statement that proceeds according to the `EventID`. For the stopwatch event, the callback sees that the `periodic` flag is set, so it calls the `adi_rtc_ResetStopwatch` function to re-enable the event, using the `NumSeconds` value to set the stopwatch counter.

Below is a code example from within the callback function where the stopwatch event is processed.

```
static void RTCCallback ( void *ClientHandle,
                          u32 Event,
                          void *pArg )

{
  STOPWATCH_INFO CountdownStruct =
```

```
    *(STOPWATCH_INFO*)ClientHandle ;

   switch ( (u32)Event )
    {
         /* stopwatch countdown timeout event */
         case ADI_RTC_EVENT_STOPWATCH:
      {
         /* increment the stopwatch event counter */
         SWEventCounter++;

         /* use the fields of the data structure
            to see whether we are done */
         /* if it's a one-shot ...*/
         if ( ( CountdownStruct.PeriodicFlag == 0 )

         /* or if it's periodic... */
         || ( (  CountdownStruct.PeriodicFlag == 1 )

         /* … but the stopwatch event counter reached
              the number of repetitions  */
         && (SWEventCounter == CountdownStruct.NumRepetitions)

         /* If NumRepetitions were 0, we would repeat forever.
            If the counter wrapped to zero, we would not stop */
         && (CountdownStruct.NumRepetitions != 0 ) ) )

 {
       adi_rtc_RemoveCallback( ADI_RTC_EVENT_STOPWATCH );
       StopwatchCompleteFlag = 1;
       SWEventCounter = 0;
 }
 else
 {
```

```
      /* the else condition means it is periodic, and either the
repetitions are unlimited or the count has not yet
reached number of repetitions, so we re-enable the event */
      adi_rtc_ResetStopwatch(  CountdownStruct.SecondsCounter );
}
 /* done */
 break;
}
```

In the main function of the example, a callback is installed for the stopwatch event. It takes a total of 20 seconds for the event to complete. The pertinent sections of the function are shown here.

```
main()
{
    int NumSeconds;
    int* pNumSeconds;

    /* to pass information when installing stopwatch callback */
    STOPWATCH_INFO StopwatchCallbackInfo;

    /* and a pointer to it */
    STOPWATCH_INFO* pStopwatchCallbackInfo;

    /* the example initializes system services including the real
        time clock service*/
    Result = adi_ssl_Init();

    /* zero this flag */
    StopwatchCompleteFlag = 0;

    /* initialize the static stopwatch event counter */
    SWEventCounter = 0;

    /* When re-enabled, the stopwatch will be set for 5 seconds*/
```

```
    StopwatchCallbackInfo.SecondsCounter = 5;

    /* stopwatch will happen periodically */
    StopwatchCallbackInfo.PeriodicFlag = 1;

    /* stopwatch will be re-enabled three times */
    StopwatchCallbackInfo.NumRepetitions = 3;

    /* point to the structure which contains the information for
         the callback */
    pStopwatchCallbackInfo = &StopwatchCallbackInfo;

    /* the first stopwatch timeout happens to be the same as the
         reset stopwatch value, 5 seconds */
    NumSeconds = StopwatchCallbackInfo.SecondsCounter;

    /* install the stopwatch callback */
    adi_rtc_InstallCallback(ADI_RTC_EVENT_STOPWATCH,
        (void*)pStopwatchCallbackInfo, NULL, RTCCallback,
          (void*)NumSeconds );

    /* wait for the stopwatch event to occur. After 5 seconds it
         will repeat three times. */
    while( StopwatchCompleteFlag == 0 );

    /* arrive here after 20 seconds */
}
```

RTC Service Application Programming Interface (API)

This section provides the details of the data structures and functions within the RTC service application program interface (API).

Notation and Naming Conventions

To safeguard against conflicts with other software libraries provided by Analog Devices (or other sources), the real-time clock service uses an unambiguous naming convention in which enumeration values and `typedef` statements use the `ADI_RTC_ prefix`. Functions and global variables use the lowercase `adi_rtc_ equivalent`.

Each function within the real-time clock service API returns an error code of the type `ADI_RTC_RESULT`. Like other system services, a return value of zero (`0=ADI_RTC_RESULT_SUCCESS`) indicates that no error occurred during the function call. Any nonzero value indicates the specific type of error that occurred. The error codes for the real-time clock service, unique from those of other system services, are defined in the `adi_rtc.h` include file, so the cause of the error can be determined from looking up the error code in that file.

The reference pages for the API functions use the following format:

Name – Name and purpose of the function

Description – Function specification

Prototype – Required header file and functional prototype

Arguments – Description of function arguments

Return Value – Description of function return values

RTC Service API Functions

This section describes the RTC functions that are available to the application. These functions read and write to the hardware registers so the application does not have to study the details of each register. Below is a list of the functions in the RTC API.

Each API function returns a value of type `ADI_RTC_RESULT` which indicates the success or failure of the function call. The result codes are defined in Table 11-4 on page 11-30. This table describes the structures and data types in the API.

adi_rtc_Init()

Description

This function initializes the real-time clock service as described in "Initialization" on page 11-2.

Prototype

```
ADI_RTC_RESULT adi_rtc_Init(
 void *pCriticalRegionArg
);
```

Arguments

The function accepts one argument of type `void*`, which is the critical region parameter.

Return Value

`ADI_RTC_RESULT_SUCCESS`	No error has been encountered.
Any other value	Error has occurred. See Table 11-4 on page 11-30 for a list of return codes.

adi_rtc_Terminate()

Description

This function terminates the real-time clock service as described in "Termination" on page 11-3.

Prototype

```
ADI_RTC_RESULT adi_rtc_Terminate(
 void
);
```

Arguments

The function takes no arguments.

Return Value

ADI_RTC_RESULT_SUCCESS	No error has been encountered.
Any other value	Error has occurred. See Table 11-4 on page 11-30 for a list of return codes.

adi_rtc_SetDateTime()

Description

This function is called to program the date and time into the RTC_STAT register. The new date and time take effect when the write completes, on the next 1 Hz tick.

Prototype

```
ADI_RTC_RESULT adi_rtc_SetDateTime(
struct tm *pDateTime
);
```

Arguments

The function accepts one argument, a pointer to the tm structure that is defined in the time.h file.

Return Value

ADI_RTC_RESULT_SUCCESS	No error has been encountered.
Any other value	Error has occurred. See Table 11-4 on page 11-30 for a list of return codes.

adi_ rtc_GetDateTime()

Description

This function is called to read the date and time from the RTC_STAT register.

Prototype

```
ADI_RTC_RESULT adi_rtc_GetDateTime( struct tm *pDateTime );
```

Arguments

The function takes one argument, a pointer to a tm structure.

Return Value

ADI_RTC_RESULT_SUCCESS	No error has been encountered.
Any other value	Error has occurred. See Table 11-4 on page 11-30 for a list of return codes.

adi_rtc_InstallCallback()

Description

This function installs a callback for a real-time clock event.

Prototype

```
ADI_RTC_RESULT  =  adi_rtc_InstallCallback(
   ADI_RTC_EVENT_ID EventID,
    void ClientHandle,
    ADI_DCB_HANDLE DCBHandle,
    ADI_DCB_CALLBACK_FN ClientCallback,
    void *Value );
```

Arguments

The caller provides five parameters to the function, shown in Table 11-1.

Table 11-1. Parameters for the InstallCallback Function

Data Type	Name	Description
ADI_RTC_EVENT_ID	EventID	Enumerator value that uniquely identifies the event for which the callback is being installed
void*	ClientHandle	Identifier defined and supplied by the application. This value is passed to the callback function.
ADI_DCB_HANDLE	DCBHandle	The handle returned from the DCB service if callbacks are deferred. NULL when callbacks are "live".
ADI_DCB_CALLBACK_FN	ClientCallback	Name of client callback function
void*	Value	RTC service uses this info to install alarm callbacks or stopwatch callbacks. It specifies number of seconds or date/time. For other callbacks, it is not used.

Return Value

ADI_RTC_RESULT_SUCCESS	No error has been encountered.
Any other value	Error has occurred. See Table 11-4 on page 11-30 for a list of return codes.

adi_rtc_RemoveCallback()

Description

This function removes the callback functionality for the specified event. It writes to the RTC_ICTL register to disable the event.

Prototype

```
ADI_RTC_RESULT adi_rtc_RemoveCallback(
 ADI_RTC_EVENT_ID EventID
);
```

Arguments

The function takes one parameter, the EventID, that specifies which of the eight possible events will have its callback removed. Refer to Table 11-1 on page 11-22 which shows the possible Event ID and its meaning.

Return Value

ADI_RTC_RESULT_SUCCESS	No error has been encountered.
Any other value	Error has occurred. See Table 11-4 on page 11-30 for a list of return codes.

adi_rtc_EnableWakeup()

Description

The adi_rtc_EnableWakeup function calls on the interrupt manager to enable the RTC bit in the system interrupt controller's wakeup register. Subsequently, all enabled RTC interrupting events generate a wake up to the processor.

Prototype

```
ADI_RTC_RESULT adi_rtc_EnableWakeup(
Void
);
```

Arguments

The function accepts no arguments. It calls the adi_int_SICWakeup function in the interrupt manager service, passing a TRUE flag.

Return Value

ADI_RTC_RESULT_SUCCESS	No error has been encountered.
Any other value	Error has occurred. See Table 11-4 on page 11-30 for a list of return codes.

adi_rtc_DisableWakeup()

Description

The adi_rtc_DisableWakeup function calls on the interrupt manager to disable the RTC bit in the system interrupt controller's wakeup register. Subsequently, none of the interrupting events wake up the processor.

Prototype

```
ADI_RTC_RESULT adi_rtc_DisableWakeup(
 void
);
```

Arguments

The function accepts no arguments (void). It calls the adi_int_SICWakeup function in the interrupt manager service, passing a FALSE flag.

Return Value

ADI_RTC_RESULT_SUCCESS	No error has been encountered.
Any other value	Error has occurred. See Table 11-4 on page 11-30 for a list of return codes.

adi_rtc_ResetStopwatch()

Description

The `adi_rtc_ResetStopwatch` function is used to re-enable a stopwatch event without reinstalling the stopwatch callback function. It can be called from inside or outside the callback, but it cannot be called unless a callback has been installed. The stopwatch event is a "one-shot" event but it may be used as a periodic event by calling this function after the stopwatch event has occurred once and the callback has executed (or is executing). This function sets the `RTC_SWCNT` register with the `NumSeconds` value and re-enables the event by writing to the `RTC_ICTL` register.

Prototype

```
ADI_RTC_RESULT adi_rtc_ResetStopwatch(
u32 NumSeconds
);
```

Arguments

A single value is passed to the function which indicates the number of seconds in the next duration of the stopwatch period.

Return Value

`ADI_RTC_RESULT_SUCCESS`	No error has been encountered.
Any other value	Error has occurred. See Table 11-4 on page 11-30 for a list of return codes.

Real-Time Clock Service API Data Types and Enumerations

This section describes the data structures for reading and writing the date and time to the RTC_STAT register, which maintains the current date and time. It also describes the asynchronous event types and the result codes that can be returned from an RTC function.

tm structure

A C-standard time structure is provided in the VisualDSP++ 5.0 system include file, time.h. This structure contains fields for the second, minute, hour, day, month, year, plus three additional fields which are not currently used by this RTC service (Table 11-2).

Table 11-2. Fields of the tm Structure

Field Type and Name	Field Description
int tm_sec	Seconds after the minute
int tm_min	Minutes after the hour
int tm_hour	Hour of the day, [0,23]
int tm_mday	Day of the month, [1,31]
int tm_mon	Months since Jan
int tm_year	Years since 1900
int tm_wday	Days since Sun, [0,6]
int tm_yday	Days since Jan 1 [0,365]
int tm_isdst	Daylight savings flag

When using adi_rtc_SetDateTime() and adi_rtc_GetDateTime(), an epoch date of the first of January 1970 is used. Although this is the earliest date that can be stored using these functions, the year should still be entered using the C standard epoch date of 1900. For example, the lowest number you can enter for this field is 70. This is because the year, month, and day fields are stored as a 15-bit day count in the RTC_STAT register which limits the length of time to 32,768 days (around 89 ½ years).

As with the standard tm structure, the tm_isdst field is not used. The adi_rtc_GetDateTime() function will always return 0 for this field.

This structure is used for compatibility with the asctime, gmtime, mktime, and ctime functions described in more detail in the C Run-Time Library reference section of the *VisualDSP++ 5.0 C/C++ Compiler and Library Manual for Blackfin Processors*.

Event IDs

There are eight possible asynchronous events that are defined by the Event ID (Table 11-3).

Table 11-3. Event ID and Description

Event Name	Event Description
ADI_RTC_EVENT_SECONDS	(0xA0001) one second periodic interrupt
ADI_RTC_EVENT_MINUTES	(0xA0002) one minute periodic interrupt
ADI_RTC_EVENT_HOURS	(0xA0003) hourly periodic interrupt
ADI_RTC_EVENT_DAYS	(0xA0004) daily periodic interrupt
ADI_RTC_EVENT_STOPWATCH	(0xA0005) stopwatch countdown event
ADI_RTC_EVENT_EACH_DAY_ALM	(0xA0006) time of day, daily alarm
ADI_RTC_EVENT_ONCE_ALM	(0xA0007) day and time once only alarm
ADI_RTC_EVENT_WRITES_COMPLETE	(0xA0008) pending register writes complete

Result Codes

Each of the RTCS API functions returns a result code that can be translated by looking into the RTC service API header file, `adi_rtc.h`. The result codes are summarized in Table 11-4.

Table 11-4. RTCS Return Values

Result Code Name	Result Code Description
ADI_RTC_RESULT_SUCCESS	Generic success = 0
ADI_RTC_RESULT_FAILED	Generic failure = 1
ADI_RTC_RESULT_START	(0xA0000) base of event code values
ADI_RTC_ENUMERATION_START	(0xA0000) base of event code values
ADI_RTC_RESULT_INVALID_EVENT_ID	(0xA0001) invalid `Event ID`
ADI_RTC_RESULT_INTERRUPT_MANAGER_ERROR	(0xA0002) error from interrupt manager
ADI_RTC_RESULT_ERROR_REMOVING_CALLBACK	(0xA0003) no callback installed for given ID
ADI_RTC_RESULT_CALL_IGNORED	(0xA0004) function not executed
ADI_RTC_RESULT_NOT_INITIALIZED	(0xA0005) RTC service was not initialized
ADI_RTC_RESULT_CALLBACK_NOT_INSTALLED	(0xA0006) callback was never installed
ADI_RTC_RESULT_DATETIME_OUT_OF_RANGE	(0xA0007) tm struct seconds field out of range
ADI_RTC_RESULT_SERVICE_NOT_SUPPORTED	(0xA0008) no RTC service for this processor
ADI_RTC_RESULT_ALREADY_INITIALIZED	(0xA0009) service was already initialized
ADI_RTC_RESULT_CALLBACK_ALREADY_INSTALLED	(0xA000A) cannot install same callback twice
ADI_RTC_RESULT_CALLBACK_CONFLICT	(0xA000B) cannot install both alarm callbacks simultaneously

Interdependencies

This section describes interdependencies between the real-time clock service and other system services.

Interrupt Manager Service

Since the real-time clock service relies on callbacks to process the events, the application must initialize the interrupt manager service before initializing the real-time clock service. During the `adi_rtc_Init()` function, the interrupt manager is called upon to "hook" the real-time clock interrupt handler which executes the callback function. During the `adi_rtc_Terminate()` function, the interrupt manager is called upon to "unhook" the real-time clock interrupt handler.

The application may choose to have real-time clock interrupts generate a wakeup signal to the processor. The real-time clock service provides an API function called `adi_rtc_DisableWakeup()`, which calls the interrupt manager function `adi_int_SICWakeup()`, passing the peripheral ID for the real-time clock, and a `FALSE` flag. The real-time clock service provides an API function called `adi_rtc_EnableWakeup()`, which calls the interrupt manager function `adi_int_SICWakeup()`, passing the peripheral ID for the real-time clock, and a `TRUE` flag, so that all real-time clock interrupting events generate a wakeup signal to the processor.

Deferred Callback Service

Callbacks may be deferred, which means that the execution of the callback is postponed to allow a higher priority thread to execute first. In this case, the callback is not executed by the interrupt handler within the interrupt service routine. Instead, the interrupt handler calls `adi_dcb_Post()` to notify the deferred callback (DCB) manager that the event has occurred. Please refer to Chapter 5, Deferred Callback Manager for details on how the DCB manager processes callbacks.

12 FILE SYSTEM SERVICE

This chapter describes the file system service (FSS). The FSS provides access to mass storage media from the Blackfin processor.

This chapter contains:

Introduction

The file system service (FSS) provides a portable and extensible means of accessing embedded mass storage media from the Blackfin processor. It is designed in such a way that support for file systems such as the FAT file system (typically found on removable media such as SD cards and USB flash drive memory sticks) and physical interfaces (such as the ATA/ATAPI interface on the ADSP-BF54x family of processors) can be added to an application with minimal effort. Support for the ADSP-BF548 EZ-KIT Lite development board is provided with VisualDSP++ 5.0 for FAT file systems on the ATA and the secure digital host interfaces for access to the attached hard disk drive and the supplied SD Card and USB flash memory drive.

An application interfaces with these drivers using a framework and API known as the file system service (FSS). Once initialized, the application can make direct calls to the FSS API functions ("File System Service API Reference" on page 12-18), or if registered, using the extensible standard C I/O interface provided with the I/O library of VisualDSP++ 5.0. Once registered with the I/O library, calls to `fopen()`, `fread()`, and so on are routed to the FSS to provide seamless access to files on the mass storage media. In this way, applications using the standard C I/O interface can be readily ported to use the file system service. In addition to these functions, support is provided for certain POSIX functions such as `opendir()`, `rename()`, `remove()`, and so on. The functions available are outlined in "Additional POSIX Functions Supported by the FSS" on page 12-71.

While the FSS API provides support for extending the declaration of file and directory names to use the Unicode UTF-8 (16-bit) specification, the current implementation of the FSS caters only for ASCII file names (8-bit).

Access to each mass storage media type in an application is provided by registering a device driver, termed a physical interface driver (PID), with the FSS. Each media is formatted for a particular file system (for example, the Microsoft® FAT file system) and the interpretation of these file systems is provided by the registration of another type of device driver termed a file system driver (FSD).

Users who wish to provide additional or replacement FSDs and PIDs for either file system or physical interface support can do so simply by following a set of design rules for the appropriate class of device driver and registering that driver with the FSS upon application initialization. Please refer to "Extensibility" on page 12-83 for further details.

The file system service is designed to function in both standalone and RTOS environments. To this end, several examples are available with VisualDSP++ 5.0 to demonstrate the configuration and use of the FSS. One particular example, the shell browser example, is a multi-threaded, VDK-based application that presents a simple, command-line interface to the file system service on a terminal emulator connected to the UART interface of the ADSP-BF548 EZ-KIT Lite. Details of these examples are provided in "Examples" on page 12-83.

Getting Started

The basics for initializing and using the file system service within an application are outlined in this section. It is assumed that the system services and device manager have already been initialized. The dependencies on the system services resources are detailed in "System Service Requirements" on page 12-7.

This section describes the overall operation of the file system service. A more complete description of the application programming interface (API) can be found later in this chapter.

Initialization

The file system service is built on the system services' device driver model and as such requires the use of both the device manager and the system services. It is necessary, therefore, to configure the application for the use of the system services and device manager before initializing the file system service. The application developer should refer to the appropriate documentation for each of the required file system drivers and physical interface drivers in order to determine which resources are required.

The file system service is configured for use by registering the required file system drivers and physical interface drivers, along with the device manager and DMA manager handles, and the handle of a deferred callback queue. This is achieved by passing a command-value pair table to the `adi_fss_Init()` API function. The simplest table is:

```
ADI_FSS_CMD_VALUE_PAIR adi_fss_Config[] = {

 /* Register the ATA/ATAPI interface driver */
 { ADI_FSS_CMD_ADD_DRIVER,         (void*)&ADI_ATAPI_Def },

 /* Register the FAT File System driver */
 { ADI_FSS_CMD_ADD_DRIVER,         (void*)&ADI_FAT_Def },

 /* Assign the DMA Manager Handle */
 { ADI_FSS_CMD_SET_DMA_MGR_HANDLE, (void*)adi_dma_ManagerHandle },

 /* Assign the Device Manager Handle */
 { ADI_FSS_CMD_SET_DEV_MGR_HANDLE, (void*)adi_dev_ManagerHandle },
```

```
 /* Assign the DCB Queue Handle */
 { ADI_FSS_CMD_SET_DCB_MGR_HANDLE, (void*)adi_dcb_QueueHandle },

 /* Command Table Terminator */
 { ADI_FSS_CMD_END, (void*)NULL }
};
```

The address of this command-value pair table is simply passed to the `adi_fss_Init()` API function as follows:

```
Result = adi_fss_Init( adi_fss_Config );
```

The above command-value pair table configures the FSS to access a hard drive attached to the ATA/ATAPI interface of the ADSP-BF54x processor. The definition structures `ADI_ATAPI_Def` and `ADI_FAT_Def` can either be defined in the application itself, or taken from the device driver header files. To do the latter, a macro must be defined ahead of the `#include` statement. The following is the quickest way to get up and running with the above command-value pair table:

```
/* FAT12/16/32 FSD driver */
#define _ADI_FAT_DEFAULT_DEF_
#include <drivers/fsd/fat/adi_fat.h>

/* ATAPI interface */
#define _ADI_ATAPI_DEFAULT_DEF_
#include <drivers/pid/atapi/adi_atapi.h>
```

To register an additional driver with the FSS, simply add the appropriate header to the file containing the above code, choose to use the default definition or supply your own, and add the following command-value pair to the FSS configuration table:

```
{ ADI_FSS_CMD_ADD_DRIVER,(void*)&<Device-Def-Structure> },
```

Please note that if the application makes simultaneous use of two or more types of media that require the use of the same file system driver, then only one `ADI_FSS_CMD_ADD_DRIVER` entry is required in the FSS configuration table for the appropriate FSD. (For example, the ADSP-BF548 EZ-KIT Lite supports access to the hard disk, an SD Card, and a USB flash memory drive, all of which can make use of the FAT file system driver.)

The complete set of commands that can be used in the initialization of the file system service is found in the description of "adi_fss_Init" on page 12-20.

The file system service is now ready for use through its direct API. However, for greater portability of applications and libraries, the FSS is best used indirectly through the standard C I/O interface. VisualDSP++ 5.0 provides the ability to extend the file I/O support beyond the host PC access (PRIMIO) that is the default. This is achieved quite simply by including the supplied FSS header file:

```
#include <services/fss/adi_fss.h>
```

and registering the required entry point structure (of type `DevEntry`) with the I/O library:

```
add_devtab_entry( &adi_fss_entry );
```

The definition of the DevEntry structure can be found in Chapter 3 of the *VisualDSP++ 5.0 C/C++ Compiler and Library Manual for Blackfin Processors*. The declaration of adi_fss_entry can be found in the file adi_fss_deventry.c in the Blackfin\lib\src\services\fss folder of the VisualDSP++ 5.0 installation.

Termination

When the application no longer requires the file system service, a call to the termination function, adi_fss_Terminate() can be made. This function unmounts all mounted file systems, closes all PIDs and FSDs, and frees all dynamically-allocated memory.

System Service Requirements

It was stated in "Getting Started" on page 12-3 that the file system service is dependent on the appropriate configuration of the system services and device manager. The recommended way to get started is to make a copy of the adi_ssl_init.c and adi_ssl_init.h files found in the FSS example folders and use them as a basis for your own applications. For example, see the sample files in:

```
Blackfin\Examples\ADSP-BF548 EZ-KIT Lite\Services\File
System\HardDisk\HardDiskAccess
```

The adi_ssl_init.c file provides the basic sequence of initialization calls to each of the system services and the device manager, supplying each service with the memory they require. The adi_ssl_init.h file contains the definitions for the constants relevant to the implementation of the FSS and is the only file of the two that requires modification. In this file, the following macros are defined to reflect the requirements of the application:

```
#define ADI_SSL_INT_NUM_SECONDARY_HANDLERS  (2)
#define ADI_SSL_DCB_NUM_SERVERS             (1)
#define ADI_SSL_DMA_NUM_CHANNELS            (2)
#define ADI_SSL_FLAG_NUM_CALLBACKS          (0)
#define ADI_SSL_SEM_NUM_SEMAPHORES          (10)
#define ADI_SSL_DEV_NUM_DEVICES             (2)
```

The values to use depends not only on the FSS configuration, that is, which file system and physical interface drivers are registered, but also on which other device drivers and services are used in the application, for example the LCD display driver, an audio codec driver, and so on.

The following sections address each of these quantities in turn, but only with respect to the file system service configuration.

Interrupt Manager Service

The interrupt manager is one of the core system services' modules that underpins the implementation of the device drivers of which the physical interface drivers (PID) are no exception. Each PID has a number of peripheral interrupts associated with it. For example, the ATAPI driver has three DMA interrupts and one device interrupt. Depending on whether you choose to use the default IVG levels for the appropriate interrupts or assign custom levels determines how many secondary interrupts are required in the application. All device drivers hook interrupt handlers to the IVG level as identified in the `SIC_IARx` registers. You may find it useful to explicitly set the required priorities with a series of calls to the `adi_int_SICSetIVG()` API function for all peripherals in your application. For example, to set the ATAPI priorities you would do the following:

```
adi_int_SICSetIVG(ADI_INT_DMA10_ATAPI_RX, 10);
adi_int_SICSetIVG(ADI_INT_DMA11_ATAPI_TX, 11);
```

```
adi_int_SICSetIVG(ADI_INT_ATAPI_ERROR, 7);
adi_int_SICSetIVG(ADI_INT_DMA_ERROR, 7);
```

In this way, you are able to see at a glance which IVG levels are used by multiple peripherals. You can then determine the number of secondary handlers (ADI_SSL_INT_NUM_SECONDARY_HANDLERS) to use.

Please refer to the device driver documentation for each PID required by your application for details of the appropriate interrupt requirements. These documents are found under the Blackfin\Docs\drivers\pid folder in the VisualDSP++ 5.0 installation.

Deferred Callback Service

The file system service is best operated using deferred callbacks. For operation within VDK it is essential that the callbacks are deferred. While multiple callback servers can be used in an application, it is recommended that just one server is used and is configured to operate at IVG level 14. In fact, for use within the VDK environment, only one server is allowed and this server makes use of the *Deferred Procedure Queue* in VDK that is executed at *Kernel* level (IVG 14).

Therefore, it is recommended that you set the value of the ADI_SSL_DCB_NUM_SERVERS macro to 1.

In addition to the code in the adi_ssl_init.c file, the following is required to *open* a queue server:

```
adi_dcb_Open( 14, DCBMgrQueue1, SIZE_DCB_QUEUE, &ResponseCount,
&adi_dcb_QueueHandle );
```

where DCBMgrQueue1 is the address of a block of memory of size at least SIZE_DCB_QUEUE. This code is extracted from the InitServices.c file in the HardDiskAccess example. The size of the queue depends on your requirements but a good starting point is to use four entries in the queue:

```
#define SIZE_DCB_QUEUE ((ADI_DCB_ENTRY_SIZE)*4)
```

DMA Service

The DMA manager is used by the file system service to transfer data between the application and the physical media, where appropriate, as determined by the nature of each PID in the application. The use of DMA and the channels affected are detailed in the appropriate PID device driver documents. The value given to the `ADI_SSL_DMA_NUM_CHANNELS` must be incremented by the number of DMA channels required by each PID.

The DMA requirements for each physical device driver are detailed in the documentation for that appropriate driver. For example, the ATAPI driver requires the DMA manager to be initialized for two DMA channels; the SD PID, one channel; and the USB host driver, no DMA channels.

Semaphore Service

The file system service requires a number of semaphores for its operation. The semaphores are used to maintain atomic access to file system and physical interface drivers and for notification of completion of data transfers. For each instance of an FSD or PID, at least two semaphores are required. (See the appropriate drive documentation for precise details.) Please note that if the application makes simultaneous use of two or more types of media that require the use of the same file system driver, then two semaphores are required for each instantiation of the appropriate FSD driver.

The number of semaphores required also varies in proportion to the number of files that are opened at one time, as the use of the file cache requires one semaphore per open file.

The value given to the `ADI_SSL_SEM_NUM_SEMAPHORES` must be incremented by the number of semaphores required for the required FSS configuration.

When the FSS is used in the VDK environment, this value is actually ignored by the semaphore service; however, you need to assign the appropriate number to the maximum active semaphores value in the kernel tab of your application project.

Real-Time Clock Service

The dependency on the real-time clock (RTC) service applies only if a file system driver, included in an application, makes use of the RTC to supply time and date details to be entered in the directory entries of new and modified files. This is the case with the FAT file system driver supplied with VisualDSP++5.0.

Initialization of the real-time clock service and how to set the current date and time are detailed in Chapter 11, Real-Time Clock Service.

Device Manager

Each PID and FSD registered by the application represents at least one device driver in the application; some PIDs such as the USB mass storage class driver may require two or more. Additionally, multiple instances of an FSD represent separate device drivers.

The value given to the `ADI_SSL_DEV_NUM_DEVICES` must be incremented by the number of PID and FSD instances appropriate for the required FSS configuration. For more details, see the appropriate device driver documentation in the folders, `Blackfin\Docs\drivers\fsd` and `Blackfin\Docs\drivers\pid`.

Advanced Configuration

This section describes how to go beyond the basics and tailor the initialization of the file system service to suit your requirements.

Custom Configuration of Device Drivers

In "Getting Started" on page 12-3, the FSD and PID definition structures used were those found in the appropriate header files for the drivers. However, there will be occasions when your application requires a customized definition, such as when additional commands need to be added to the driver's configuration table.

The device definition structures are of type `ADI_FSS_DEVICE_DEF` which is described in "File System Service API Data Types and Enumerations" on page 12-51. This structure is defined in the FSS header file, `<services/fss/adi_fss.h>`.

The command table is an array of command-value pairs (type `ADI_DEV_CMD_VALUE_PAIR`) that are usual for device drivers that conform to the system services' device driver model.

Valid commands for the driver configuration table are presented in the individual driver documents, found in the VisualDSP++ 5.0 installation in the appropriate sub-folder under `Blackfin\Docs\drivers\fsd` or `Blackfin\Docs\drivers\pid`. An example would be to assign a heap index for the allocation of DMA buffers (see "Dynamic Memory Usage" on page 12-14):

```
ADI_DEV_CMD_VALUE_PAIR ADI_FAT_ConfigTable [] = {
        { ADI_FSS_CMD_SET_CACHE_HEAP_ID,   (void*)2 },
        { ADI_DEV_CMD_END,                 NULL     },
};
```

In addition to being able to customize the definition of a PID, it is possible to register a PID that has already been opened and configured. This facility is primarily provided to enable the swapping of mass storage media between the FSS and other elements of an application. For example embedded NAND flash, hard disk, or SD card could be swapped between the FSS and the USB mass storage (device) class driver to enable access to the embedded mass storage from a PC or Mac.

Before the PID can be registered in this way it must be:

- **Opened:** The values in the `ADI_FSS_DEVICE_DEF` structure defined in the PID header file can be used in an explicit call to `adi_dev_Open`. For example, the members of the ATAPI device definition structure can be used as follows:

```
adi_dev_Open (adi_dev_ManagerHandle,
              ADI_ATAPI_Def.pEntryPoint,
              ADI_ATAPI_Def.DeviceNumber,
              <client handle>,
              &ADI_ATAPI_Def.DeviceHandle,
              ADI_ATAPI_Def.Direction,
              adi_dma_ManagerHandle,
              adi_dcb_QueueHandle,
              <client-callback-function>);
```

  Please note that the `<client-handle>` and `<client callback-function>` arguments only have meaning prior to registration of the PID with the file system service; these items are reassigned within the FSS. If they have no direct relevance to the application itself, they can be assigned NULL and 1 respectively.

- **Data Flow Method Assigned:** The data flow method of the PID must be set to `ADI_DEV_MODE_CHAINED` with the following command-value pair:

  ```
  {ADI_DEV_CMD_SET_DATAFLOW_METHOD,(void *)
  ADI_DEV_MODE_CHAINED}
  ```

- **Configured:** In addition to setting the data flow method, the PID should be configured at the very least with the commands defined in the command table whose location is given by the `pConfigTable` member of the appropriate device definition structure.

Registration of the PID can either be accomplished by passing the following command-value pair to `adi_fss_Control`:

```
{ADI_FSS_CMD_REGISTER_DEVICE,(void *)&ADI_ATAPI_Def}
```

or by using the `adi_fss_RegisterDevice` function:

```
{adi_fss_RegisterDevice(&ADI_ATAPI_Def,1);
```

For further details, see the definition of this function in the section "File System Service API Reference" on page 12-18.

Dynamic Memory Usage

In a departure from other system services and device drivers, the file system service makes extensive use of dynamically-allocated memory for internal data structures and DMA buffers.

This is largely due to the somewhat arbitrary and indeterminate nature of the memory requirements associated with file systems, where buffer sizes depend on the media present and the file system used. The use of dynamic memory within all parts of the FSS framework frees the application developer from having to estimate the amount of memory required at build time.

However, in order to give the application developer some control, all dynamic memory requests throughout the FSS and its component file system and physical interface drivers are made through centralized functions, which then make calls into the C library functions or can be directed to call custom functions for either greater efficiency or monitoring purposes. There are three heap allocation functions for `malloc`, `realloc`, and `free` operations, and all three must be replaced with custom functions if any are to be replaced. To use your own functions, ensure that the functions you wish to use conform to the following prototypes for each operation.

```
malloc:

void *<custom-heap_malloc-function>( int, size_t );

realloc:

void *<custom-heap_realloc-function>( int, void *, size_t );

free:

void  <custom-heap_free-function>( int, void * );
```

These are then required to be registered with the file system service using the following command-value pairs:

```
{ ADI_FSS_CMD_SET_MALLOC_FUNC,
   (void*)<custom-heap_malloc-function>  },
{ ADI_FSS_CMD_SET_REALLOC_FUNC,
   (void*)<custom-heap_realloc-function> },
{ ADI_FSS_CMD_SET_FREE_FUNC,
   (void*)<custom-heap_free-function>    },
```

Furthermore, memory allocation is divided into two categories of memory requirement: *general* memory is defined as the memory required for data structures such as device driver instance data and file descriptors, and so on, and *cache* memory is defined as the memory required for cache-type buffers such as DMA transfer buffers. Management of these categories of memory is implemented by the use of custom (or user) heaps, available with VisualDSP++ 5.0. Each component of the FSS framework allocates general memory off the single *general* heap defined in the FSS. For cache memory requirements, each component can be assigned a separate *cache* heap to use.

Two commands are defined to assign the indexes of general and cache heaps. To assign the general heap index, use the following command-value pair in the FSS configuration table passed to the `adi_fss_Init()` function only:

```
  { ADI_FSS_CMD_SET_GENERAL_HEAP_ID, (void*)GeneralHeap },
```

The `GeneralHeap` value is the array index of the heap entry in the `heap_table`. For example, in “Shell_Browser” on page 12-86, the `GeneralHeap` value is assigned to 1 which is the index of the `FSSGeneralHeap_space` entry in the following table[1]:

```
struct heap_table_t heap_table[4] =
{
  { &ldf_heap_space, (int) &ldf_heap_length, 0 },
  { &FSSGeneralHeap_space, (int) &FSSGeneralHeap_length, 1 },
  { &FSSCacheHeap_space, (int) &FSSCacheHeap_length, 2 },
  { 0, 0, 0 }
};
```

This index can also be obtained from a call to `heap_lookup()` for the `userid` required:

```
  GeneralHeap = heap_lookup(1);
```

[1] Please note that this is also the userid value in the table entry, which is a coincidental consequence of the above entries being auto-generated by the project options wizard. For user heaps defined with heap_install, this may not be the case.

To assign a cache heap use:

```
{ ADI_FSS_CMD_SET_CACHE_HEAP_ID, (void*)CacheHeap },
```

which can be added to the configuration table of each driver and the `adi_fss_Init()` function. In the latter case, it is used to assign the heap index for allocation of each file cache buffer. See "File Cache" on page 12-17 for further details.

The default case is for all cache heaps to default to the general heap, and the general heap to default to the system heap. This is the case for the configuration shown in "Getting Started" on page 12-3. Please note that while it is perfectly valid to use the same cache heap index for each driver (FSD or PID), the heap index is required to be registered with each device driver through its configuration table.

File Cache

The file system service is designed to use a file cache when appropriate. This cache, which is allocated from the FSS cache heap, ("Dynamic Memory Usage" on page 12-14), acts as a read-ahead, write-behind cache so as to enhance data transfer rates in either direction. To achieve higher transfer rates, cache blocks are transferred to or from the media in the background, and its use is thus optimal for physical interface drivers that use peripheral DMA. The decision to use a file cache for a file is taken by the FSS upon opening a file, when the respective file system driver and physical interface drivers are queried to determine whether a file cache can be supported. Please refer to the appropriate FSD and PID documentation for details. For example, the FAT and ATAPI drivers for access to the hard disk on the ADSP-BF548 EZ-KIT Lite support the use of a file cache.

Each file cache comprises a number of blocks, each the size of the smallest addressable unit within the respective file system. For example, in the FAT file system, the block size is that of a cluster. The cluster size depends on the size and format (for example, FAT12, FAT16 or FAT32) of the media. The FSS requests the block size from the appropriate FSD upon opening a file. The number of cache blocks to use defaults to four (4), but can be overridden upon initialization of the FSS with the inclusion of the following command-value pair in the FSS configuration table:

```
{ ADI_FSS_CMD_SET_NUMBER_CACHE_BLOCKS,
   (void*)<number-cache-blocks> },
```

When a file is opened, the file cache is dynamically allocated from the FSS cache heap; when the file is closed, the memory is freed.

Please note that for the default format of the hard disk of the ADSP-BF548 EZ-KIT Lite, a cluster—and hence each cache block—is 16 KB in size.

File System Service API Reference

This section provides the details of the data structures and functions within the FSS or file system service application program interface (API). It is usually intended that the API be used via intermediate code such as the extensible. Its use may provide marginal benefits in terms of throughput speed and code size, but this is offset by its lack of portability between development environments.

Notation and Naming Conventions

To safeguard against conflicts with other software libraries provided by Analog Devices, or other sources, the file system service uses an unambiguous naming convention in which enumeration values and `typedef` statements use the `ADI_FSS_` prefix. Functions and global variables use the lowercase `adi_fss_` equivalent.

Each function within the file system service API returns an error code of type `ADI_FSS_RESULT`. Like the other system services, a return value of zero (`ADI_FSS_RESULT_SUCCESS`) indicates that no error has occurred during the function call. Any nonzero value indicates the specific type of error that has occurred. The error codes for the file system service are unique from those of the other system services, and are defined in the `adi_fss.h` header file and in "File System Service API Data Types and Enumerations" on page 12-51. The cause of the error can be determined by looking up the error code in the file. The reference pages for the API functions use the following format:

Name – Name and purpose of the function

Description – Function specification

Prototype – Required header file and functional prototype

Arguments – Description of function arguments

Return Value – Description of function return values

adi_fss_Init

Description

This function initializes the file system service and prepares it for operation. Configuration is effected by supplying a table of command-value pairs. The only mandatory commands are:

ADI_FSS_CMD_ADD_DRIVER	(0xB0005) Sets the location of the ADI_FSS_DEVICE_DEF structure defining either a file system driver (FSD) or physical interface driver (PID). This command is mandatory only for FSDs.
ADI_FSS_CMD_SET_DEV_MGR_HANDLE	(0xB000E) Sets device manager handle

In addition to these commands, others may also be used as appropriate for the physical interface and file system drivers present in the overall configuration. Please refer to the relevant driver documentation for further details. The optional commands are:

ADI_FSS_CMD_SET_DMA_MGR_HANDLE	(0xB000D) Sets DMA manager handle. It is required only if a PID uses peripheral DMA.
ADI_FSS_CMD_SET_DCB_MGR_HANDLE	(0xB000F) Sets DCB queue manager handle. It is strongly recommended to use deferred callbacks in a standalone application, and compulsory in a VDK application.
ADI_FSS_CMD_SET_CACHE_HEAP_ID	(0xB0011) Heap ID for cache blocks
ADI_FSS_CMD_SET_GENERAL_HEAP_ID	(0xB0014) Heap ID for file descriptors
ADI_FSS_CMD_SET_NUMBER_CACHE_BLOCKS	(0xB0012) Number of cache blocks to use (min 2)
ADI_FSS_CMD_SET_NUMBER_CACHE_SUB_BLOCKS	(0xB0013) Number of cache sub-blocks to use (min 1). It is highly recommended not to alter this value.
ADI_FSS_CMD_SET_MALLOC_FUNC	(0xB0006) Sets client malloc function
ADI_FSS_CMD_SET_REALLOC_FUNC	(0xB0007) Sets client realloc function

ADI_FSS_CMD_SET_FREE_FUNC	(0xB0008) Sets client `free` function
ADI_FSS_CMD_SET_VOLUME_SEPARATOR	(0xB0009) Sets volume separator character
ADI_FSS_CMD_SET_DIRECTORY_SEPARATOR	(0xB000A) Sets directory separator character
ADI_FSS_CMD_SET_MEDIA_CHANGE_CALLBACK	(0xB001B) Sets the `ADI_DCB_CALLBACK_FN` callback function that is called when the media is changed; for example, when a USB flash drive or SD card is inserted or removed.
ADI_FSS_CMD_SET_MEDIA_CHANGE_HANDLE	(0xB001C) Sets the handle that is sent as the first argument to the callback function upon media change.
ADI_FSS_CMD_SET_DATA_SEMAPHORE_TIMEOUT	(0xB001D) Sets the timeout argument for all semaphore pends within the context of the FSS. This value must be the logical OR of the timeout value in ticks and the appropriate value to prevent an RTOS error condition on timeout.
ADI_FSS_CMD_SET_TRANSFER_RETRY_COUNT	(0xB001E) Sets the number of times a transfer is retried after a semaphore timeout. The value includes the initial attempt, so a value of one means no retries after the timeout. This is the default.
ADI_FSS_CMD_REGISTER_DEVICE	(0xB0019) Registers a physical interface driver by specifying the location of the appropriate `ADI_FSS_DEVICE_DEF` structure. Prior to using this command, the appropriate device driver must be opened and configured.

Prototype

```
ADI_FSS_RESULT adi_fss_Init (
                            ADI_FSS_CMD_VALUE_PAIR *pTable
);
```

Arguments

pTable	Pointer to table of command-pair values used to initialize the FSS module

Return Value

ADI_FSS_RESULT_SUCCESS	No error has been encountered.
Any other value	Error has occurred. See Table 12-1 on page 12-55 for a list of return codes.

adi_fss_Terminate

Description

This function terminates the file system service.

Prototype

```
ADI_FSS_RESULT adi_fss_Terminate ( void );
```

Arguments

The function takes no arguments.

Return Value

`ADI_FSS_RESULT_SUCCESS`	No error has been encountered.
Any other value	Error has occurred. See Table 12-1 on page 12-55 for a list of return codes.

adi_fss_Control

Description

This function is called to send specific commands to the FSS service module for control of operations. Valid command codes are:

Command Code Name	Command Code Description
ADI_FSS_CMD_END	(0xB0002) End of table of control-command pairs
ADI_FSS_CMD_PAIR	(0xB0003) Value is pointer to control-command pair
ADI_FSS_CMD_TABLE	(0xB0004) Value is pointer to table of control-command pairs
ADI_FSS_CMD_GET_NUMBER_VOLUMES	(0xB000B) Gets the number of available partitions
ADI_FSS_CMD_GET_VOLUME_INFO	(0xB000C) Gets information regarding available partitions
ADI_FSS_CMD_FORMAT_VOLUME	(0xB4017) Formats a volume
ADI_FSS_CMD_REGISTER_DEVICE	(0xB0019) Registers a physical interface driver by specifying the location of the appropriate ADI_FSS_DEVICE_DEF structure. Prior to using this command, the appropriate device driver must be opened and configured.
ADI_FSS_CMD_DEREGISTER_DEVICE	(0xB001A) Deregisters the handle of a physical interface device.
ADI_FSS_CMD_SET_MEDIA_CHANGE_CALLBACK	(0xB001B) Sets the ADI_DCB_CALLBACK_FN callback function that is called when the media is changed; for example, when a USB flash drive or SD card is inserted or removed.
ADI_FSS_CMD_SET_MEDIA_CHANGE_HANDLE	(0xB001C) Sets the handle that is sent as the first argument to the callback function upon media change.

Command Code Name	Command Code Description
ADI_FSS_CMD_SET_DATA_SEMAPHORE_TIMEOUT	(0xB001D) Sets the timeout argument for all semaphore pends within the context of the FSS. This value must be the logical OR of the timeout value in ticks and the appropriate value to prevent an RTOS error condition on timeout.
ADI_FSS_CMD_SET_TRANSFER_RETRY_COUNT	(0xB001E) Sets the number of times a transfer is retried after a semaphore timeout. The value includes the initial attempt, so a value of one means no retries after the timeout. This is the default. After all attempts have failed, the FSS reports the error back to the application.

Prototype

```
u32 adi_fss_Control (
                    u32     CommandID,
                    void    *Value
);
```

Arguments

CommandID	Command ID
Value	Pointer to command-specific value

Return Value

ADI_FSS_RESULT_SUCCESS	No error has been encountered.
Any other value	Error has occurred. See Table 12-1 on page 12-55 for a list of return codes.

adi_fss_RegisterDevice

Description

This function is called to register a physical interface driver (PID) with the FSS. Upon registration, the PID is activated. Media detection can also be performed dependent on the value of the PollForMedia argument.

Prototype

```
u32 adi_fss_RegisterDevice (
        ADI_FSS_DEVICE_DEF     *pDeviceDef,
        u32                    PollForMedia
);
```

Arguments

pDeviceDef	The location of the device definition structure for the required physical interface driver
PollForMedia	Flag to determine whether to poll for media after activation. Set 1 to poll, 0 otherwise. If polling is not chosen, the application must explicitly poll for media

Return Value

ADI_FSS_RESULT_SUCCESS	No error has been encountered.
Any other value	Error has occurred. See Table 12-1 on page 12-55 for a list of return codes.

adi_fss_DeRegisterDevice

Description

This function is called to deregister a physical interface driver (PID) with the FSS. All associated volumes will be unmounted and the device deactivated.

Prototype

```
u32 adi_fss_DeRegisterDevice (
        ADI_DEV_DEVICE_HANDLE     DeviceHandle
);
```

Arguments

DeviceHandle	The device handle of the physical interface driver that is to be deregistered with the FSS

Return Value

ADI_FSS_RESULT_SUCCESS	No error has been encountered.
Any other value	Error has occurred. See Table 12-1 on page 12-55 for a list of return codes.

adi_fss_PollMediaOnDevice

Description

This function is called to poll the media associated with the given PID device handle.

Prototype

```
u32 adi_fss_PollMediaOnDevice (
        ADI_DEV_DEVICE_HANDLE     DeviceHandle
);
```

Arguments

`DeviceHandle`	The device handle of the required physical interface driver

Return Value

`ADI_FSS_RESULT_SUCCESS`	No error has been encountered.
Any other value	Error has occurred. See Table 12-1 on page 12-55 for a list of return codes.

adi_fss_UnMountDevice

Description

This function is called to unmount all volumes on the media associated with the given PID device handle. The device remains registered with the FSS.

Prototype

```
u32 adi_fss_UnMountDevice (
        ADI_DEV_DEVICE_HANDLE     DeviceHandle
);
```

Arguments

DeviceHandle	The device handle of the required physical interface driver

Return Value

ADI_FSS_RESULT_SUCCESS	No error has been encountered.
Any other value	Error has occurred. See Table 12-1 on page 12-55 for a list of return codes.

adi_fss_FileOpen

Description

This function opens a file stream for reading or writing. The name argument can be specified as an absolute or relative path. Valid mode values are given in the following table. Combinations of mode values may be required. For example, to open a file for append would require the mode to be specified as `ADI_FSS_MODE_WRITE | ADI_FSS_MODE_APPEND`.

ADI_FSS_MODE_READ	Read-only access
ADI_FSS_MODE_WRITE	Write access only
ADI_FSS_MODE_READ_WRITE	Read and write access
ADI_FSS_MODE_APPEND	Append mode
ADI_FSS_MODE_CREATE	Create file if not found
ADI_FSS_MODE_TRUNCATE	Truncate file if existing file opened for write

Prototype:

```
ADI_FSS_RESULT adi_fss_FileOpen  (
                    ADI_FSS_WCHAR         *name,
                    u32                   namelen,
                    u32                   mode,
                    ADI_FSS_FILE_HANDLE   *FileHandle );
```

Arguments

`name`	NULL-terminated string identifying file to open
`namelen`	Length of name string excluding NULL; for example, the value that the `strlen(name)` would return
`mode`	Mode in which file is opened
`FileHandle`	Location to store handle identifying file stream

Return Value

`ADI_FSS_RESULT_SUCCESS`	No error has been encountered.
Any other value	Error has occurred. See Table 12-1 on page 12-55 for a list of return codes.

adi_fss_FileClose

Description

This function closes the file stream identified by `FileHandle`.

Prototype:

```
adi_fss_FileClose ( ADI_FSS_FILE_HANDLE FileHandle );
```

Arguments

`FileHandle`	Handle identifying file stream

Return Value

`ADI_FSS_RESULT_SUCCESS`	No error has been encountered.
Any other value	Error has occurred. See Table 12-1 on page 12-55 for a list of return codes.

adi_fss_FileWrite

Description

This function writes the `size` number of bytes of data identified by `buf` to a file stream identified by `FileHandle` and returns the number of bytes written to the location pointed at by the `BytesWritten` pointer.

Prototype

```
u32 adi_fss_FileWrite (
                      ADI_FSS_FILE_HANDLE FileHandle,
                      u8          *buf,
                      u32         size,
                      u32         *BytesWritten
 );
```

Arguments

`FileHandle`	Handle identifying file stream
`buf`	Start address of buffer to write
`size`	Number of bytes to write
`BytesWritten`	Location to store actual size written

Return Value

`ADI_FSS_RESULT_SUCCESS`	No error has been encountered.
Any other value	Error has occurred. See Table 12-1 on page 12-55 for a list of return codes.

adi_fss_FileRead

Description

The adi_fss_FileRead function reads data from a file stream identified by FileHandle, places it in the buffer identified by buf, and returns the number of bytes read into the location pointed to by the BytesRead pointer.

Prototype

```
u32 adi_fss_FileRead (
                     ADI_FSS_FILE_HANDLE FileHandle,
                     u8          *buf,
                     u32         size,
                     u32         *BytesRead
 );
```

Arguments

FileHandle	Handle identifying file stream
buf	Start address of buffer to fill
size	Number of bytes to read
BytesRead	Location to store actual size read

Return Value

ADI_FSS_RESULT_SUCCESS	No error has been encountered.
Any other value	Error has occurred. See Table 12-1 on page 12-55 for a list of return codes.

adi_fss_FileSeek

Description

The adi_fss_FileSeek function moves the current file position to the location defined by the Offset and Origin arguments.

The Origin value should have one of the following values (defined in stdio.h):

SEEK_SET	Seek from the start of the file
SEEK_CUR	Seek from the current location
SEEK_END	Seek from the end of the file

You can use adi_fss_FileSeek to move beyond the end of a file, but not before the beginning. Using adi_fss_FileSeek clears the EOF flag associated with that stream.

Prototype

```
u32 adi_fss_FileSeek (
                    ADI_FSS_FILE_HANDLE FileHandle,
                    s32         offset,
                    u32         Origin,
                    u32         *tellpos
);
```

Arguments

`FileHandle`	Handle identifying file stream
`offset`	Offset (in bytes) from Origin location
`Origin`	Location to begin seek from
`tellpos`	Location to store current position after seek

Return Value

`ADI_FSS_RESULT_SUCCESS`	No error has been encountered.
Any other value	Error has occurred. See Table 12-1 on page 12-55 for a list of return codes.

adi_fss_FileTell

Description

The adi_fss_FileTell function reports the current position in the file.

Prototype

```
u32 adi_fss_FileTell (
                    ADI_FSS_FILE_HANDLE    FileHandle
                    u32                    *tellpos
);
```

Arguments

FileHandle	Handle identifying file stream
tellpos	Location to store current position

Return Value

ADI_FSS_RESULT_SUCCESS	No error has been encountered.
Any other value	Error has occurred. See Table 12-1 on page 12-55 for a list of return codes.

adi_fss_IsEOF

Description

This function determines if the end of the file on the indicated data stream has been reached.

Prototype:

```
u32 adi_fss_IsEOF(  ADI_FSS_FILE_HANDLE FileHandle );
```

Arguments

FileHandle	Handle identifying file stream

Return Value

ADI_FSS_RESULT_SUCCESS	No error has been encountered.
ADI_FSS_RESULT_EOF	End of file has been reached.
Any other value	Error has occurred. See Table 12-1 on page 12-55 for a list of return codes.

adi_fss_FileRemove

Description

This routine removes the specified file. The `name` argument can be specified as an absolute or relative path.

Prototype

```
u32 adi_fss_FileRemove (
                        ADI_FSS_WCHAR   *name,
                        u32             namelen
);
```

Arguments

`name`	NULL-terminated string identifying file to remove
`namelen`	Length of name string excluding terminating NULL; for example, the value that `strlen(name)` would return

Return Value

`ADI_FSS_RESULT_SUCCESS`	No error has been encountered.
Any other value	Error has occurred. See Table 12-1 on page 12-55 for a list of return codes.

adi_fss_FileRename

Description

This routine renames a file from old_path to new_path. Both arguments can be specified as absolute or relative paths.

Prototype

```
u32 adi_fss_FileRename (
                         ADI_FSS_WCHAR   *old_path,
                         u32             oldlen,
                         ADI_FSS_WCHAR   *new_path,
                         u32             newlen
);
```

Arguments

old_path	NULL-terminated string identifying file to rename
oldlen	Length of old_path string excluding terminating NULL; for examaple, the value that strlen(name) would return
new_path	NULL-terminated string identifying new file name
newlen	Length of new_path string excluding NULL; for example, the value that strlen(name) would return

Return Value

ADI_FSS_RESULT_SUCCESS	No error has been encountered.
Any other value	Error has occurred. See Table 12-1 on page 12-55 for a list of return codes.

adi_fss_DirOpen

Description

This routine opens the specified directory stream. The `name` argument can be specified as an absolute or relative path.

Prototype

```
u32 adi_fss_DirOpen  (
                     ADI_FSS_WCHAR        *name,
                     u32                  namelen,
                     ADI_FSS_DIR_HANDLE   *DirHandle
);
```

Arguments

`name`	NULL-terminated string identifying the directory to open
`namelen`	Length of name string excluding terminating NULL; for example, the value that `strlen(name)` would return
`DirHandle`	Location to store handle identifying directory stream

Return Value

`ADI_FSS_RESULT_SUCCESS`	No error has been encountered.
Any other value	Error has occurred. See Table 12-1 on page 12-55 for a list of return codes.

adi_fss_DirClose

Description

This routine closes the identified directory stream.

Prototype:

```
u32 adi_fss_DirClose ( ADI_FSS_DIR_HANDLE DirHandle );
```

Arguments

DirHandle	Handle identifying directory stream

Return Value

ADI_FSS_RESULT_SUCCESS	No error has been encountered.
Any other value	Error has occurred. See Table 12-1 on page 12-55 for a list of return codes.

adi_fss_DirRead

Description

This routine returns a pointer to the next directory entry from the directory stream.

Prototype:

```
u32 adi_fss_DirRead (
                    ADI_FSS_DIR_HANDLE   DirHandle,
                    ADI_FSS_DIR_ENTRY    **pDirEntry
);
```

Arguments

DirHandle	Handle identifying directory stream
pDirEntry	Location to store pointer to directory entry structure

Return Value

ADI_FSS_RESULT_SUCCESS	No error has been encountered.
Any other value	Error has occurred. See Table 12-1 on page 12-55 for a list of return codes.

adi_fss_DirSeek

Description

This routine seeks to the specific place in a directory stream specified by `DirHandle`. The `Seekpos` argument should be obtained from a previous call to `adi_fss_DirTell()`.

Prototype

```
u32 adi_fss_DirSeek (
                    ADI_FSS_DIR_HANDLE   DirHandle,
                    u32                  Seekpos
);
```

Arguments

`DirHandle`	Handle identifying directory stream
`Seekpos`	Position (in bytes) in directory stream to seek

Return Value

`ADI_FSS_RESULT_SUCCESS`	No error has been encountered.
Any other value	Error has occurred. See Table 12-1 on page 12-55 for a list of return codes.

adi_fss_DirTell

Description

This routine reports the current position (in bytes) in the specified directory stream.

Prototype

```
u32 adi_fss_DirTell (
                    ADI_FSS_DIR_HANDLE    DirHandle,
                    u32                   *tellpos
);
```

Arguments

DirHandle	Handle identifying directory stream
tellpos	Location to store current position

Return Value

ADI_FSS_RESULT_SUCCESS	No error has been encountered.
Any other value	Error has occurred. See Table 12-1 on page 12-55 for a list of return codes.

adi_fss_DirRewind

Description

This routine rewinds the specified directory stream to its beginning.

Prototype

```
u32 adi_fss_DirRewind ( ADI_FSS_DIR_HANDLE DirHandle );
```

Arguments

DirHandle	Handle identifying directory stream

Return Value

ADI_FSS_RESULT_SUCCESS	No error has been encountered.
Any other value	Error has occurred. See Table 12-1 on page 12-55 for a list of return codes.

adi_fss_DirChange

Description

This routine changes the current working directory, from which relative file paths are evaluated. The `name` value can be specified as either a relative or absolute path.

Prototype

```
u32 adi_fss_DirChange (
                      ADI_FSS_WCHAR  *name,
                      u32            namelen
);
```

Arguments

`name`	NULL-terminated string identifying new current working directory
`namelen`	Length of name string excluding terminating NULL; for example, the value that `strlen(name)` would return

Return Value

`ADI_FSS_RESULT_SUCCESS`	No error has been encountered.
Any other value	Error has occurred. See the Table 12-1 on page 12-55 for a list of return codes.

adi_fss_GetCurrentDir

Description

This routine returns the name of the current working directory.

Prototype

```
u32 adi_fss_GetCurrentDir (
                          ADI_FSS_WCHAR   *name,
                          u32             *namelen
);
```

Arguments

name	Array to store NULL-terminated string containing the current working directory
namelen	Location to store length of name array

Return Value

ADI_FSS_RESULT_SUCCESS	No error has been encountered.
Any other value	Error has occurred. See Table 12-1 on page 12-55 for a list of return codes.

adi_fss_DirCreate

Description

This routine creates a specified directory. The `name` argument can be specified as an absolute or relative path, provided that all intermediate directories exist.

Prototype

```
u32 adi_fss_DirCreate  (
                        ADI_FSS_WCHAR    *name,
                        u32              namelen,
                        u32              mode
);
```

Arguments

`name`	NULL-terminated string identifying directory to open
`namelen`	Length of name string excluding terminating NULL; for example, the value that `strlen(name)` would return
`mode`	Mode of newly-created directory (ignored). This argument is reserved for future use.

Return Value

`ADI_FSS_RESULT_SUCCESS`	No error has been encountered.
Any other value	Error has occurred. See Table 12-1 on page 12-55 for a list of return codes.

adi_fss_DirRemove

Description

This routine removes the specified directory. The `name` argument can be specified as an absolute or relative path.

Prototype

```
u32 adi_fss_DirRemove  (
                        ADI_FSS_WCHAR   *name,
                        u32             namelen
);
```

Arguments

`name`	NULL-terminated string identifying directory to remove
`namelen`	Length of name string excluding terminating NULL; for example, the value that `strlen(name)` would return

Return Value

`ADI_FSS_RESULT_SUCCESS`	No error has been encountered.
Any other value	Error has occurred. See Table 12-1 on page 12-55 for a list of return codes.

File System Service API Data Types and Enumerations

This section describes the data types used by the FSS API and the result code enumerations.

ADI_FSS_WCHAR

The ADI_FSS_WCHAR data type is used for all file and directory names used in the FSS API. As mentioned in the "Introduction" on page 12-2, the current implementation of the FSS caters only for ASCII file names (8-bit). This data type is defined as:

```
typedef char ADI_FSS_WCHAR;
```

ADI_FSS_VOLUME_IDENT

The ADI_FSS_VOLUME_IDENT data type is used for the identifiers of each mounted volume. The data type is defined as:

```
typedef char ADI_FSS_VOLUME_IDENT;
```

ADI_FSS_FILE_HANDLE

The ADI_FSS_FILE_HANDLE is an opaque data type used to uniquely identify the file stream to manipulate. It is defined as:

```
typedef void *ADI_FSS_FILE_HANDLE;
```

ADI_FSS_DIR_HANDLE

The ADI_FSS_DIR_HANDLE is an opaque data type used to uniquely identify the directory stream to manipulate. It is defined as:

```
typedef void *ADI_FSS_DIR_HANDLE;
```

ADI_FSS_CMD_VALUE_PAIR

The ADI_FSS_CMD_VALUE_PAIR data type is a structure containing a command code and an associated value. These command-value pairs are used in the FSS configuration table and in calls to adi_fss_Control(). The appropriate commands are detailed at "adi_fss_Init" on page 12-20 and "adi_fss_Control" on page 12-24. The structure is defined as:

```
typedef struct {
    u32     CommandID;                              */
    void    *Value;
} ADI_FSS_CMD_VALUE_PAIR;
```

where the fields are assigned as shown in the following table.

CommandID	ID of command to execute
Value	Associated value as appropriate for the command ID

ADI_FSS_DIR_ENTRY

The ADI_FSS_DIR_ENTRY data type is a structure that contains the details of a directory entry. The structure is identical to the POSIX struct dirent structure:

```
typedef struct dirent ADI_FSS_DIR_ENTRY;
```

The struct dirent structure is described in the POSIX documentation (see "Additional POSIX Functions Supported by the FSS" on page 12-71 for the location of this document) and is defined in the FSS header file, <services/fss/adi_fss.h>.

ADI_FSS_DEVICE_DEF

The ADI_FSS_DEVICE_DEF data type defines a structure to contain the information required to open and configure an FSD or PID device driver. It is defined as:

```
typedef struct {
    u32                        DeviceNumber;
    ADI_DEV_PDD_ENTRY_POINT    *pEntryPoint;
    ADI_DEV_CMD_VALUE_PAIR     *pConfigTable;
    void                       *pCriticalRegionData;
    ADI_DEV_DIRECTION          Direction;
    ADI_DEV_DEVICE_HANDLE      DeviceHandle;
    ADI_FSS_VOLUME_IDENT       DefaultMountPoint;
} ADI_FSS_DEVICE_DEF;
```

where the assigned fields are shown in the following table.

DeviceNumber	This defines which peripheral device to use. This is the DeviceNumber argument required for a call to adi_dev_Open(). See the appropriate driver documentation for valid values.
pEntryPoint	This is a pointer to the device driver entry points and is passed as the pEntryPoint argument required for a call to adi_dev_Open(). See the appropriate driver header file and documentation for the entry point declaration.
pConfigTable	This is a pointer to the table of command-value pairs to configure the device driver. If no commands are required, this value can be set to NULL.
pCriticalRegionData	This is a pointer to the argument that should be passed to the system services adi_int_EnterCriticalRegion() function. This is currently not used and should be set to NULL.
Direction	This is the Direction argument required for a call to adi_dev_Open(). See the appropriate driver documentation for valid values.
DeviceHandle	This is the location used internally to store the device driver handle on return from a call to adi_dev_Open(). It should be set to NULL prior to initialization.
DefaultMountPoint	This is the default drive letter used for volumes managed by the driver. This is especially useful for removable media types such as USB memory sticks, SD cards, and optical media. This can be left as NULL if no preference is desired.

Result Codes

Each of the FSS API functions returns a result code that can be interpreted by looking up the value in the FSS service API header file, `adi_fss.h`. The result codes are summarized in Table 12-1.

Table 12-1. Result Codes

Result Code Name	Result Code Description
ADI_FSS_RESULT_SUCCESS	Generic success = 0
ADI_FSS_RESULT_FAILED	Generic failure = 1
ADI_FSS_RESULT_OPEN_FAILED	(0XB0001) file/directory open failure (media fault)
ADI_FSS_RESULT_NOT_FOUND	(0XB0002) file/directory not found
ADI_FSS_RESULT_CLOSE_FAILED	(0XB0003) file/directory close failure (media fault)
ADI_FSS_RESULT_NO_MEDIA	(0xB0004) no media detected
ADI_FSS_RESULT_MEDIA_CHANGED	(0xB0005) media has changed since last check
ADI_FSS_RESULT_MEDIA_FULL	(0xB0006) no room left on media
ADI_FSS_RESULT_NO_MEMORY	(0xB0007) insufficient memory to perform request
ADI_FSS_RESULT_INVALID_DEVICE	(0xB0008) device driver cannot be initialized
ADI_FSS_RESULT_BAD_FILE_HANDLE	(0xB0009) no valid file descriptor at address supplied
ADI_FSS_RESULT_BAD_NAME	(0xB000A) invalid path specified for file/directory

Table 12-1. Result Codes (Cont'd)

Result Code Name	Result Code Description
ADI_FSS_RESULT_EOF	(0xB000B) end of file reached
ADI_FSS_RESULT_EOD	(0xB000C) end of directory reached
ADI_FSS_RESULT_BAD_VOLUME	(0xB000D) invalid partition specified
ADI_FSS_RESULT_NOT_SUPPORTED	(0xB000E) command code is not supported
ADI_FSS_RESULT_TIMEOUT	(0xB0010) timeout has occurred
ADI_FSS_RESULT_BAD_CACHE_HANDLE	(0xB0011) bad cache handle
ADI_FSS_RESULT_CANT_CREATE_SEMAPHORE	(0xB0012) cannot create semaphore in file cache

The Standard C I/O Interface Functions

This section briefly details the standard C I/O API. By registering the FSS with the C I/O library as detailed in Chapter 3 of the *C and C++ Compiler and Linker Manual for Blackfin Processors*, and as described in "Getting Started" on page 12-3, calls to functions in this section are routed to the FSS after processing by the I/O library. All functions follow the POSIX convention for the argument and return types. Please refer to a suitable C textbook for futher details.

This list details most of the available functions, but any function defined in `<stdio.h>` for file access results in appropriate (primitive) calls to the FSS API.

fopen

Description

The `fopen` function opens a named file in accordance to the mode flags.

Prototype

```
FILE * fopen ( const char *name, const char *mode );
```

fclose

Description

The `fclose` function closes a file identified by `stream`.

Prototype

```
int fclose ( FILE * stream);
```

fwrite

Description

The `fwrite` function writes `num` data elements of `size` bytes to the file identified by `stream`.

Prototype

```
int fwrite (void *buffer, size_t size, size_t num, FILE *stream);
```

fread

Description

The fread function reads num data elements of size bytes from the file identified by stream.

Prototype

```
int fread (void *buffer, size_t size, size_t num, FILE *stream);
```

fprintf

Description

The `fprintf` function writes to the file identified by `stream` as determined by the format string. The VisualDSP++ 5.0 I/O library performs all the required format processing.

Prototype

```
int fprintf  (FILE *stream, const char *fmt, ...);
```

fscanf

Description

The `fscanf` function reads from the file identified by `stream` as determined by the format string. The VisualDSP++ 5.0 I/O library performs all the required format processing.

Prototype

```
int fscanf  (FILE *stream, const char *fmt, ...);
```

fgetc

Description

The `fgetc` function reads the next byte from the file identified by `stream`.

Prototype

```
int fgetc  (FILE *stream);
```

fgets

Description

The `fgets` function reads the next `n` bytes from the file identified by `stream` into the `buf` character array.

Prototype

```
char * fgets  (char *buf, int n, FILE *stream );
```

fputc

Description

The `fputc` function writes the `ci` byte to the file indentified by `stream`.

Prototype

```
int fputc  (int ci, FILE *stream );
```

fputs

Description

The `fputs` function writes the text string, `s`, to the file indentified by `stream`.

Prototype

```
int fputs  (const char *s, FILE *stream );
```

fseek

Description

The `fseek` function moves the current file position.

Prototype

```
int fseek  (FILE *stream, long offset, int origin );
```

ftell

Description

The `ftell` function returns the current position in a file.

Prototype

```
long ftell   (FILE *stream );
```

feof

Description

The `feof` function returns whether the current file is at end-of-file (EOF).

Prototype

```
int feof  (FILE *stream );
```

Additional POSIX Functions Supported by the FSS

This section provides a brief listing of the additional POSIX functions and structures supported by the FSS system service. A more comprehensive description of the routine can be found with an internet search on the function name or through viewing the function's reference page in *The Single UNIX® Specification, Version 2, System Interface & Headers Reference Pages*, available online at:

http://www.opengroup.org/onlinepubs/007908775/xshix.html.

The functions listed in this section have no implementation within the VisualDSP++ 5.0 I/O library except for `rename()` and `remove()`. These two functions also exist within the VisualDSP++ 5.0 I/O library but are limited to PRIMIO access to the file system of the host PC.

To use all functions in this section, you will need to include the FSS header file, `<services/fss/adi_fss.h>`, in your application source file. By including this header file, all references to rename and remove in the source file will resolve to the FSS variants for these functions.

opendir

Description

This function opens the specified directory for processing by `readdir`, `readdir_r`, `telldir`, `seekdir`, `rewinddir`, and `closedir`.

Prototype

```
DIR *opendir ( const char *dirname )
```

closedir

Description

This function closes access to a directory structure pointed to by the `dirp` argument.

Prototype

```
int closedir ( DIR * dirp )
```

readdir

Description

This function returns a pointer to a `dirent` structure representing the next directory entry in the specified directory stream. It returns NULL on reaching the end-of-file or if an error occurred. The filenames are returned in the order in which they are stored by the file system.

Prototype

```
struct dirent *readdir ( DIR *dirp )
```

readdir_r

Description

This function behaves similarly to readdir but instead of returning a pointer to a dirent structure it populates the structure referenced by the entry argument with the details of the directory entry at the current position in the directory stream. A pointer to this structure is also returned in the location specified by the result argument. This location will contain NULL upon reaching the end of the directory stream. Like readdir it positions the directory stream at the next entry upon return.

Prototype

```
int readdir_r ( DIR *dirp, struct dirent *entry, struct dirent
**result )
```

rewinddir

Description

This function rewinds the specified directory.

Prototype

```
void rewinddir ( DIR *dirp )
```

seekdir

Description

The `seekdir()` function sets the position of the next `readdir()` operation on the directory stream specified by `dirp` to the position specified by `loc`.

Prototype

```
void seekdir ( DIR *dirp,  long loc );
```

telldir

Description

The `telldir()` function obtains the current location associated with the specified directory stream.

Prototype

```
long telldir ( DIR *dirp );
```

mkdir

Description

The `mkdir` function creates the specified directory. The `mode` argument is ignored by the FSS.

Prototype

```
int mkdir ( const char *path, mode_t mode )
```

rmdir

Description

The `rmdir` utility deletes the specified directory.

Prototype

```
int rmdir ( const char *path );
```

rename

Description

The `rename` function renames the file from `_oldnm` to `_newnm`.

Prototype

```
int rename ( const char *_oldnm, const char *_newnm );
```

remove

Description

The `remove` function removes the specified file.

Prototype

```
int remove ( const char *_filename );
```

Extensibility

The file system service supports a straightforward and simple approach to the insertion of additional or replacement drivers, to support different file systems (FSDs) to interpret the media attached to new or existing physical interfaces (PIDs).

New device drivers for insertion into the FSS must conform to either the FSD or PID design documents supplied with VisualDSP++ 5.0:

```
Blackfin\docs\drivers\fsd\Generic_FSD_Design_Document.pdf,
Blackfin\docs\drivers\pid\Generic_PID_Design_Document.pdf,
```

These documents detail how the drivers interface with the other components of the file system service framework.

Once created, the driver is directly available for incorporation within the FSS. All that is required is to declare an `ADI_FSS_DEVICE_DEF` structure (and accompanying configuration table if required) and register it with the FSS via the `ADI_FSS_CMD_ADD_DRIVER` command:

```
{ ADI_FSS_CMD_ADD_DRIVER,(void*)&<Device-Def-Structure> },
```

The details of the `ADI_FSS_DEVICE_DEF` structure are described in "File System Service API Data Types and Enumerations" on page 12-51.

Examples

Included with VisualDSP++ 5.0 are some examples to demonstrate how the FSS is configured and how it can be used. As examples, their scope of operation has been purposely limited; please employ caution when using them as a basis for your own applications. The examples described in this section are all specific to the ADSP-BF548 EZ-KIT Lite development board. Similar examples may exist for the ADSP-BF527 EZ-KIT Lite development board but will use only the USB host mass storage interface to access USB flash drives.

Three examples are included. The first (*HardDiskAccess)* shows how to get started with the file system service. The second (*HardDiskFormat*) is somewhat more complex and demonstrates how to use the constituent drivers away from the FSS in order to format the hard disk drive, especially if it has never been formatted previously. The final example (*Shell_Browser*) is a multi-threaded, VDK-based application demonstrating the use of the file system service within a multi-threaded, multi-peripheral environment.

HardDiskAccess

This simple program (the *Hello World* of the FSS) demonstrates the basic configuration of the file system service and its use.

Description

This example program performs the following operations:

1. Shows the characteristics of the FAT partition.
2. Creates a sub-directory on a hard disk.
3. Moves to that directory.
4. Creates a file in that directory.
5. Lists the contents of that directory.
6. Performs a checksum operation on the created file and displays the results.
7. Removes that file.
8. Moves back to the root directory.

9. Removes the sub-directory.
10. Exits the program.

This program assumes an attached hard drive that has been previously formatted as a single FAT partition. The file created is filled with known data and the checksum operation checks against a previously-calculated checksum value to ensure data integrity. Please note that the timestamps of the created files may appear arbitrary. This is due to the fact that the real-time clock (RTC) may have not been set yet. See the `Shell_Browser` application for details of setting the RTC.

Configuration

The `HardDiskAccess` example initializes the FSS for:

- Two cache blocks per file
- The ATA/ATAPI driver
- The FAT file system

Configuration is performed in the `InitfileSystem.c` file with a call to `adi_fss_Init()` by passing it the address of the `adi_fss_config` array. Then, the FSS system is added to the C runtime library device table. When configured, the FSS service becomes the default for file access via the standard I/O interface.

HardDiskFormat

This program is used to format the attached hard disk as a single, 32GB FAT 32 partition. This example is only relevant to the ADSP-BF548 EZ-KIT Lite development board.

Examples

Description

This example program is a simple, standalone application that initializes the SSL, loads the ATAPI PID, attaches to the ATAPI hard disk, formats the disk, and then exits.

Configuration

The application only initializes the FSS in as far as establishing the general heap index, for memory allocation within the drivers. Otherwise, both the ATAPI PID and FAT FSD drivers are configured and accessed directly to format the partition and create the master boot record (MBR).

Shell_Browser

This application provides a simple shell interface to the file system service to navigate the media available and perform certain operations such as displaying a slideshow of bitmap files to the LCD attached to the ADSP-BF548 EZ-KIT Lite.

Description

This example program uses three threads—a communication thread to interface with an I/O console connected to the UART interface, an image display thread to view images on the LCD panel, and a command thread to control the application and perform non-image related file tasks. The communication thread collects the input from the I/O console and passes it to the command thread. The image display thread takes an image file or a list of image files and displays the images to the LCD panel. The command thread interprets the input commands and performs the required actions. A full list of the commands supported is available by typing "help" or "?". Likewise, the syntax of any individual command can be obtained by typing the command followed by `-h`. For example, `rmdir -h` lists the syntax and purpose of the command.

Since the example consists of three separate threads, the order of initialization and interoperability is important. The command thread performs the initialization of the system services prior to the other threads being executed. The image display thread and the console thread are reliant on the fact that all required system services have been initialized already.

Configuration

The `Shell_Browser` sets up the FSS for:

- Two cache blocks per file
- The ATA/ATAPI driver
- The SD card driver
- The USB host mass storage driver
- The FAT file system
- The UART device driver for data transmission

When the example is running, it:

- Registers the UART console driver to be used for `stdin` and `stdout`
- Initializes the image viewer LCD driver
- Starts the image viewer thread

Once all three threads are running, the program is ready to accept keyboard input and perform the input operations. Note that the `Shell_Browser` application makes extensive use of most of the different system services to perform its operations. Its utility is not limited to simply showing the operation of the file system service, but extends to giving an example of the use of system services and device drivers, and the FSS in particular, in a threaded environment.

Examples

Please note that the timestamps of any created files may appear arbitrary. This is due to the fact that the real-time clock (RTC) may have not been set yet. This can be achieved using the date command. For example, to set the date to 2:30 P.M. on Monday, September 17, 2007, enter the following at the prompt: `date mon 091714302007`. Enter `'date -h'` for full usage details.

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