

Introduction

This chapter describes the MicroC/OS-II real-time kernel for the Nios® II processor. This chapter contains the following sections:

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- “The Nios II Implementation of MicroC/OS-II ” on page 10-2
- “Implementing MicroC/OS-II Projects for the Nios II Processor” on page 10-6

Overview

MicroC/OS-II is a popular real-time kernel produced by Micrium Inc. MicroC/OS-II is a portable, ROMable, scalable, preemptive, real-time, multitasking kernel. First released in 1992, MicroC/OS-II is used in hundreds of commercial applications. It is implemented on more than 40 different processor architectures in addition to the Nios II processor.

MicroC/OS-II provides the following services:

- Tasks (threads)
- Event flags
- Message passing
- Memory management
- Semaphores
- Time management

The MicroC/OS-II kernel operates on top of the hardware abstraction layer (HAL) board support package (BSP) for the Nios II processor. Because of this architecture, MicroC/OS-II development for the Nios II processor has the following advantages:

- Programs are portable to other Nios II hardware systems.
- Programs are resistant to changes in the underlying hardware.
- Programs can access all HAL services, calling the UNIX-like HAL application program interface (API).
- ISRs are easy to implement.

Further Information



This chapter discusses the details of how to use MicroC/OS-II for the Nios II processor only. For complete reference of MicroC/OS-II features and usage, refer to *MicroC/OS-II - The Real-Time Kernel* by Jean J. Labrosse (CMP Books). You can obtain further information from Micrium (www.micrium.com).

Licensing

Altera distributes MicroC/OS-II in the Nios II Embedded Design Suite (EDS) for evaluation purposes only. If you plan to use MicroC/OS-II in a commercial product, you must obtain a license from Micrium (www.micrium.com).



Micrium offers free licensing for universities and students. Contact Micrium for details.

Other RTOS Providers

Altera distributes MicroC/OS-II to provide you with immediate access to an easy-to-use RTOS. In addition to MicroC/OS-II, many other RTOSs are available from third-party vendors.



For a complete list of RTOSs that support the Nios II processor, visit the [Embedded Software](#) page of the Altera website.

The Nios II Implementation of MicroC/OS-II

Altera has ported MicroC/OS-II to the Nios II processor. Altera distributes MicroC/OS-II in the Nios II EDS, and supports the Nios II implementation of the MicroC/OS-II kernel. Ready-made, working examples of MicroC/OS-II programs are installed with the Nios II EDS. In addition, Nios development boards are preprogrammed with a web server reference design based on MicroC/OS-II and the NicheStack® TCP/IP Stack - Nios II Edition.

The Altera implementation of MicroC/OS-II is designed to be easy to use. Using the Nios II project settings, you can control the configuration for all the RTOS's modules.

You need not modify source files directly to enable or disable kernel features. Nonetheless, Altera provides the Nios II processor-specific source code in case you wish to examine it. The MicroC/OS-II source code is located in the following directories:

- Processor-specific code: *<Nios II EDS install path>/components/altera_nios2/UCOSII*
- Processor-independent code: *<Nios II EDS install path>/components/micrium_uc_osii*

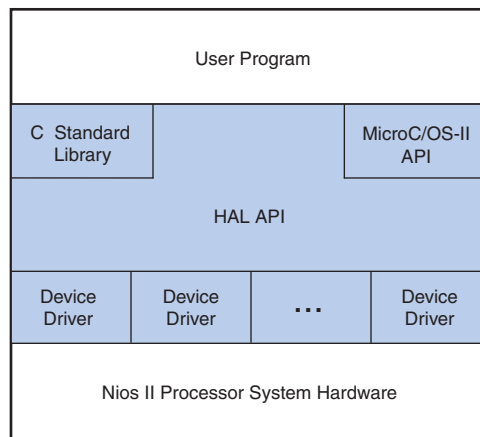
The MicroC/OS-II software package behaves like the drivers for SOPC Builder hardware components: When MicroC/OS-II is included in a Nios II project, the header and source files from **components/micrium_uc_osii** are included in the project path, causing the MicroC/OS-II kernel to compile and link as part of the project.

MicroC/OS-II Architecture


The Altera implementation of MicroC/OS-II for the Nios II processor extends the single-threaded HAL environment to include the MicroC/OS-II scheduler and the associated MicroC/OS-II API. The complete HAL API is available to all MicroC/OS-II projects.

Figure 10-1 shows the architecture of a program based on MicroC/OS-II and its relationship to the HAL API.

Figure 10-1. Architecture of MicroC/OS-II Programs




The multi-threaded environment affects certain HAL functions.

 For details about the consequences of calling a particular HAL function in a multi-threaded environment, refer to the *HAL API Reference* chapter of the *Nios II Software Developer's Handbook*.


MicroC/OS-II Thread-Aware Debugging

When you debug a MicroC/OS-II application, the debugger can display the current state of all threads in the application, including backtraces and register values. You cannot use the debugger to change the current thread, so it is not possible to use the debugger to change threads or to single-step a different thread.

 Thread-aware debugging does not change the behavior of the target application in any way.

MicroC/OS-II Device Drivers

Each peripheral (that is, each SOPC Builder component) can provide include files and source files in the **inc** and **src** subdirectories of the component's **HAL** directory.

 For more information, refer to the *Developing Device Drivers for the Hardware Abstraction Layer* chapter of the *Nios II Software Developer's Handbook*.

In addition to the **HAL** directory, a component can optionally provide a **UCOSII** directory that contains code specific to the MicroC/OS-II environment. Similar to the **HAL** directory, the **UCOSII** directory contains **inc** and **src** subdirectories.

When you create a MicroC/OS-II project, either with the Nios II software build tools or with the Nios II integrated development environment (IDE), these directories are added to the search paths for source and include files.

The Nios II software build tools copy the files to your BSP's **obj** subdirectory.

- For more information about specifying file paths with the Nios II software build tools, refer to “Board Support Packages” in the *Using the Nios II Software Build Tools* chapter of the *Nios II Software Developer’s Handbook*.

You can use the **UCOSII** directory to provide code that is used only in a multi-threaded environment. Other than these additional search directories, the mechanism for providing MicroC/OS-II device drivers is identical to the process for any other device driver.

- For details about developing device drivers, refer to the *Developing Device Drivers for the Hardware Abstraction Layer* chapter of the *Nios II Software Developer’s Handbook*.

The HAL system initialization process calls the MicroC/OS-II function `OSInit()` before `alt_sys_init()`, which instantiates and initializes each device in the system. Therefore, the complete MicroC/OS-II API is available to device drivers, although the system is still running in single-threaded mode until the program calls `OSStart()` from within `main()`.

Thread-Safe HAL Drivers

To enable a driver to be ported between the HAL and MicroC/OS-II environments, Altera defines a set of operating system-independent macros that provide access to operating system facilities. These macros implement functionality that is only relevant to a multi-threaded environment. When compiled for a MicroC/OS-II project, the macros expand to MicroC/OS-II API calls. When compiled for a single-threaded HAL project, the macros expand to benign empty implementations. These macros are used in Altera-provided device driver code, and you can use them if you need to write a device driver with similar portability.

Table 10-1 lists the available macros and their functions.

- For more information about the functionality in the MicroC/OS-II environment, refer to *MicroC/OS-II: The Real-Time Kernel*.

The path listed for the header file is relative to the `<Nios II EDS install path>/components/micrium_uc_osii/UCOSII/inc` directory.

Table 10-1. OS-Independent Macros for Thread-Safe HAL Drivers (Part 1 of 2)

Macro	Defined in Header	MicroC/OS-II Implementation	Single-Threaded HAL Implementation
<code>ALT_FLAG_GRP(group)</code>	<code>os/alt_flag.h</code>	Create a pointer to a flag group with the name <code>group</code> .	Empty statement.
<code>ALT_EXTERN_FLAG_GRP(group)</code>	<code>os/alt_flag.h</code>	Create an external reference to a pointer to a flag group with name <code>group</code> .	Empty statement.
<code>ALT_STATIC_FLAG_GRP(group)</code>	<code>os/alt_flag.h</code>	Create a static pointer to a flag group with the name <code>group</code> .	Empty statement.
<code>ALT_FLAG_CREATE(group, flags)</code>	<code>os/alt_flag.h</code>	Call <code>OSFlagCreate()</code> to initialize the flag group pointer, <code>group</code> , with the flags value <code>flags</code> . The error code is the return value of the macro.	Return 0 (success).

Table 10-1. OS-Independent Macros for Thread-Safe HAL Drivers (Part 2 of 2)

Macro	Defined in Header	MicroC/OS-II Implementation	Single-Threaded HAL Implementation
ALT_FLAG_PEND(<i>group</i> , <i>flags</i> , <i>wait_type</i> , <i>timeout</i>)	os/alt_flag.h	Call OSFlagPend() with the first four input arguments set to <i>group</i> , <i>flags</i> , <i>wait_type</i> , and <i>timeout</i> respectively. The error code is the return value of the macro.	Return 0 (success).
ALT_FLAG_POST(<i>group</i> , <i>flags</i> , <i>opt</i>)	os/alt_flag.h	Call OSFlagPost() with the first three input arguments set to <i>group</i> , <i>flags</i> , and <i>opt</i> respectively. The error code is the return value of the macro.	Return 0 (success).
ALT_SEM(<i>sem</i>)	os/alt_sem.h	Create an OS_EVENT pointer with the name <i>sem</i> .	Empty statement.
ALT_EXTERN_SEM(<i>sem</i>)	os/alt_sem.h	Create an external reference to an OS_EVENT pointer with the name <i>sem</i> .	Empty statement.
ALT_STATIC_SEM(<i>sem</i>)	os/alt_sem.h	Create a static OS_EVENT pointer with the name <i>sem</i> .	Empty statement.
ALT_SEM_CREATE(<i>sem</i> , <i>value</i>)	os/alt_sem.h	Call OSSemCreate() with the argument <i>value</i> to initialize the OS_EVENT pointer <i>sem</i> . The return value is zero on success, or negative otherwise.	Return 0 (success).
ALT_SEM_PEND(<i>sem</i> , <i>timeout</i>)	os/alt_sem.h	Call OSSemPend() with the first two argument set to <i>sem</i> and <i>timeout</i> respectively. The error code is the return value of the macro.	Return 0 (success).
ALT_SEM_POST(<i>sem</i>)	os/alt_sem.h	Call OSSemPost() with the input argument <i>sem</i> .	Return 0 (success).

The Newlib ANSI C Standard Library

Programs based on MicroC/OS-II can also call the ANSI C standard library functions. Some consideration is necessary in a multi-threaded environment to ensure that the C standard library functions are thread-safe. The newlib C library stores all global variables in a single structure referenced through the pointer `_impure_ptr`. However, the Altera MicroC/OS-II implementation creates a new instance of the structure for each task. During a context switch, the value of `_impure_ptr` is updated to point to the current task's version of this structure. In this way, the contents of the structure pointed to by `_impure_ptr` are treated as thread local. For example, through this mechanism each task has its own version of `errno`.

This thread-local data is allocated at the top of the task's stack. You must make allowance for thread-local data storage when allocating memory for stacks. In general, the `_reent` structure consumes approximately 900 bytes of data for the normal C library, or 90 bytes for the reduced-footprint C library.



For further details about the contents of the `_reent` structure, refer to the newlib documentation. On the Windows Start menu, click **Programs > Altera > Nios II > Nios II Documentation**.


In addition, the MicroC/OS-II implementation provides appropriate task locking to ensure that heap accesses (calls to `malloc()` and `free()`) are also thread-safe.

Interrupt Service Routines for MicroC/OS-II

Implementing ISRs for MicroC/OS-II normally involves some housekeeping details, as described in *MicroC/OS-II: The Real-Time Kernel*. However, because the Nios II implementation of MicroC/OS-II is based on the HAL, several of these details are taken care of for you. The HAL performs the following housekeeping tasks for your interrupt service routine (ISR):


- Saves and restores processor registers
- Calls `OSIntEnter()` and `OSIntExit()`

The HAL also allows you to write your ISR in C, rather than assembly language.


 For more detail about writing ISRs with the HAL, refer to the *Exception Handling* chapter of the *Nios II Software Developer's Handbook*.

Implementing MicroC/OS-II Projects for the Nios II Processor

To create a program based on MicroC/OS-II, start by setting the BSP properties so that it is a MicroC/OS-II project. You can control the configuration of the MicroC/OS-II kernel using BSP settings through the Nios II IDE, or with the Nios II command-line software build tools development flow.

 You do not need to edit header files (such as `OS_CFG.h`) or source code to configure the MicroC/OS-II features. The project settings are reflected in the BSP's `system.h` file; `OS_CFG.h` simply includes `system.h`.

The following sections define the MicroC/OS-II settings available through the Nios II IDE.

 For information about how to configure MicroC/OS-II with BSP settings, refer to the *Using the Nios II Software Build Tools* and *Nios II Software Build Tools Reference* chapters of the *Nios II Software Developer's Handbook*. For step-by-step instructions on how to create a MicroC/OS-II project in the Nios II IDE, refer to *Using the MicroC/OS-II RTOS with the Nios II Processor Tutorial*. The meaning of each setting is defined fully in *MicroC/OS-II: The Real-Time Kernel*.

MicroC/OS-II General Options

Table 10-2 shows the general MicroC/OS-II options available through the Nios II IDE.

Table 10-2. General Options (Part 1 of 2)

Option	Description
Maximum number of tasks	Specifies the value of the <code>OS_MAX_TASKS</code> preprocessor symbol. Must be at least 2
Lowest assignable priority	Specifies the value of the <code>OS_LOWEST_PRIO</code> preprocessor symbol. Maximum allowable value is 63.
Thread safe C library	Enable thread-safe C library

Table 10-2. General Options (Part 2 of 2)

Option	Description
Enable code for event flags	Specifies the value of the <code>OS_FLAG_EN</code> preprocessor symbol. When this option is disabled (set to 0), event flag settings are also disabled. Refer to “Event Flag Settings” on page 10-7.
Enable code for mutex semaphores	Specifies the value of the <code>OS_MUTEX_EN</code> preprocessor symbol. When this option is disabled (set to 0), mutual exclusion semaphore settings are also disabled. Refer to “Mutex Settings” on page 10-7.
Enable code for semaphores	Specifies the value of the <code>OS_SEM_EN</code> preprocessor symbol. When this option is disabled (set to 0), semaphore settings are also disabled. Refer to “Semaphore Settings” on page 10-8.
Enable code for mailboxes	Specifies the value of the <code>OS_MBOX_EN</code> preprocessor symbol. When this option is disabled (set to 0), mailbox settings are also disabled. Refer to “Mailbox Settings” on page 10-8.
Enable code for queues	Specifies the value of the <code>OS_Q_EN</code> preprocessor symbol. When this option is disabled (set to 0), queue settings are also disabled. Refer to “Queue Settings” on page 10-8.
Enable code for memory management	Specifies the value of the <code>OS_MEM_EN</code> preprocessor symbol. When this option is disabled (set to 0), memory management settings are also disabled. Refer to “Memory Management Settings” on page 10-9.
Enable code for timers	Enable code for timers

Event Flag Settings

Table 10-3 shows the event flag settings available through the Nios II IDE.

Table 10-3. Event Flags Settings

Setting	Description
Include code for wait on clear in the event flags	Specifies the value of the <code>OS_FLAG_WAIT_CLR_EN</code> preprocessor symbol. This setting includes code to wait for the specified bits to be cleared in the event flag group.
Include code for OSFlagAccept()	Specifies the value of the <code>OS_FLAG_ACCEPT_EN</code> preprocessor symbol.
Include code for OSFlagDel()	Specifies the value of the <code>OS_FLAG_DEL_EN</code> preprocessor symbol.
Include code for OSFlagQuery()	Specifies the value of the <code>OS_FLAG_QUERY_EN</code> preprocessor symbol.
Maximum number of event flag groups	Specifies the value of the <code>OS_MAX_FLAGS</code> preprocessor symbol.
Size of name of event flags group	Specifies the value of the <code>OS_FLAG_NAME_SIZE</code> preprocessor symbol.
Event flag bits (8, 16, 32)	Specifies the number of event flag bits

Mutex Settings

Table 10-4 shows the mutex settings available through the Nios II IDE.

Table 10-4. Mutex Settings

Setting	Description
Include code for OSMutexAccept()	Specifies the value of the <code>OS_MUTEX_ACCEPT_EN</code> preprocessor symbol.
Include code for OSMutexDel()	Specifies the value of the <code>OS_MUTEX_DEL_EN</code> preprocessor symbol.
Include code for OSMutexQuery()	Specifies the value of the <code>OS_MUTEX_QUERY_EN</code> preprocessor symbol.

Semaphore Settings

Table 10-5 shows the semaphore settings available through the Nios II IDE.

Table 10-5. Semaphores Settings

Setting	Description
Include code for OSSemAccept()	Specifies the value of the <code>OS_SEM_ACCEPT_EN</code> preprocessor symbol.
Include code for OSSemSet()	Specifies the value of the <code>OS_SEM_SET_EN</code> preprocessor symbol.
Include code for OSSemDel()	Specifies the value of the <code>OS_SEM_DEL_EN</code> preprocessor symbol.
Include code for OSSemQuery()	Specifies the value of the <code>OS_SEM_QUERY_EN</code> preprocessor symbol.

Mailbox Settings

Table 10-6 shows the mailbox settings available through the Nios II IDE.

Table 10-6. Mailboxes Settings

Setting	Description
Include code for OSMBboxAccept()	Specifies the value of the <code>OS_MBOX_ACCEPT_EN</code> preprocessor symbol.
Include code for OSMBboxDel()	Specifies the value of the <code>OS_MBOX_DEL_EN</code> preprocessor symbol.
Include code for OSMBboxPost()	Specifies the value of the <code>OS_MBOX_POST_EN</code> preprocessor symbol.
Include code for OSMBboxPostOpt()	Specifies the value of the <code>OS_MBOX_POST_OPT_EN</code> preprocessor symbol.
Include code for OSMBboxQuery()	Specifies the value of the <code>OS_MBOX_QUERY_EN</code> preprocessor symbol.

Queue Settings

Table 10-7 shows the queue settings available through the Nios II IDE.

Table 10-7. Queues Settings

Setting	Description
Include code for OSQAccept()	Specifies the value of the OS_Q_ACCEPT_EN preprocessor symbol.
Include code for OSQDel()	Specifies the value of the OS_Q_DEL_EN preprocessor symbol.
Include code for OSQFlush()	Specifies the value of the OS_Q_FLUSH_EN preprocessor symbol.
Include code for OSQPost()	Specifies the value of the OS_Q_POST_EN preprocessor symbol.
Include code for OSQPostFront()	Specifies the value of the OS_Q_POST_FRONT_EN preprocessor symbol.
Include code for OSQPostOpt()	Specifies the value of the OS_Q_POST_OPT_EN preprocessor symbol.
Include code for OSQQuery()	Specifies the value of the OS_Q_QUERY_EN preprocessor symbol.
Maximum number of Queue Control blocks	Specifies the value of the OS_MAX_QS preprocessor symbol.

Memory Management Settings

Table 10-8 shows the memory management settings available through the Nios II IDE.

Table 10-8. Memory Management Settings

Setting	Description
Include code for OSMemQuery()	Specifies the value of the OS_MEM_QUERY_EN preprocessor symbol.
Maximum number of memory partitions	Specifies the value of the OS_MAX_MEM_PART preprocessor symbol.
Size of memory partition name	Specifies the value of the OS_MEM_NAME_SIZE preprocessor symbol.

Miscellaneous Settings

Table 10-9 shows the miscellaneous settings available through the Nios II IDE.

Table 10-9. Miscellaneous Settings (Part 1 of 2)

Setting	Description
Enable argument checking	Specifies the value of the OS_ARG_CHK_EN preprocessor symbol.
Enable uCOS-II hooks	Specifies the value of the OS_CPU_HOOKS_EN preprocessor symbol.
Enable debug variables	Specifies the value of the OS_DEBUG_EN preprocessor symbol.
Include code for OSSchedLock() and OSSchedUnlock()	Specifies the value of the OS_SCHED_LOCK_EN preprocessor symbol.

Table 10-9. Miscellaneous Settings (Part 2 of 2)

Setting	Description
Enable tick stepping feature for uCOS-View	Specifies the value of the <code>OS_TICK_STEP_EN</code> preprocessor symbol.
Enable statistics task	Specifies the value of the <code>OS_TASK_STAT_EN</code> preprocessor symbol.
Check task stacks from statistics task	Specifies the value of the <code>OS_TASK_STAT_STK_CHK_EN</code> preprocessor symbol.
Statistics task stack size	Specifies the value of the <code>OS_TASK_STAT_STK_SIZE</code> preprocessor symbol.
Idle task stack size	Specifies the value of the <code>OS_TASK_IDLE_STK_SIZE</code> preprocessor symbol.
Maximum number of event control blocks	Specifies the value of the <code>OS_MAX_EVENTS</code> preprocessor symbol.
Size of semaphore, mutex, mailbox, or queue name	Specifies the value of the <code>OS_EVENT_NAME_SIZE</code> preprocessor symbol.

Task Management Settings

Table 10-10 shows the task management settings available through the Nios II IDE.

Table 10-10. Task Management Settings

Setting	Description
Include code for OSTaskChangePrio()	Specifies the value of the <code>OS_TASK_CHANGE_PRIO_EN</code> preprocessor symbol.
Include code for OSTaskCreate()	Specifies the value of the <code>OS_TASK_CREATE_EN</code> preprocessor symbol.
Include code for OSTaskCreateExt()	Specifies the value of the <code>OS_TASK_CREATE_EXT_EN</code> preprocessor symbol.
Include code for OSTaskDel()	Specifies the value of the <code>OS_TASK_DEL_EN</code> preprocessor symbol.
Include variables in OS_TCB for profiling	Specifies the value of the <code>OS_TASK_PROFILE_EN</code> preprocessor symbol.
Include code for OSTaskQuery()	Specifies the value of the <code>OS_TASK_QUERY_EN</code> preprocessor symbol.
Include code for OSTaskSuspend() and OSTaskResume()	Specifies the value of the <code>OS_TASK_SUSPEND_EN</code> preprocessor symbol.
Include code for OSTaskSwHook()	Specifies the value of the <code>OS_TASK_SW_HOOK_EN</code> preprocessor symbol.
Size of task name	Specifies the value of the <code>OS_TASK_NAME_SIZE</code> preprocessor symbol.

Time Management Settings

Table 10-11 shows the time management settings available through the Nios II IDE.

Table 10-11. Time Management Settings

Setting	Description
Include code for OSTimeDlyHMSM()	Specifies the value of the <code>OS_TIME_DLY_HMSM_EN</code> preprocessor symbol.
Include code for OSTimeDlyResume()	Specifies the value of the <code>OS_TIME_DLY_RESUME_EN</code> preprocessor symbol.
Include code for OSTimeGet() and OSTimeSet()	Specifies the value of the <code>OS_TIME_GET_SET_EN</code> preprocessor symbol.
Include code for OSTimeTickHook()	Specifies the value of the <code>OS_TIME_TICK_HOOK_EN</code> preprocessor symbol.

Timer Management Settings

Table 10-12 shows the timer management settings available through the Nios II IDE.

Table 10-12. Timer Management Settings

Setting	Description
Maximum number of timers	Specifies the aximum number of timers
Determine the size of a timer name	Specifies the the size of a timer name
Size of timer wheel (#Spokes)	Specifies the size of the timer wheel
Rate at which timer management task runs (Hz)	Specifies the rate at which the timer management task runs
Stack size for timer task	Specifies the stack space allocated for the timer task
Priority of timer task (0=highest)	Specifies the timer task priority

Referenced Documents

This chapter references the following documents:

- *Using the Nios II Software Build Tools* chapter of the *Nios II Software Developer's Handbook*
- *Developing Device Drivers for the Hardware Abstraction Layer* chapter of the *Nios II Software Developer's Handbook*
- *Exception Handling* chapter of the *Nios II Software Developer's Handbook*
- *HAL API Reference* chapter of the *Nios II Software Developer's Handbook*
- *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*
- *Using the MicroC/OS-II RTOS with the Nios II Processor Tutorial*
- *MicroC/OS-II: The Real-Time Kernel*, Jean J. Labrosse, CMP Books
- newlib ANSI C standard library documentation installed with the Nios II EDS
- The *Embedded Software* page of the Altera website

Document Revision History

Table 10-13 shows the revision history for this document.

Table 10-13. Document Revision History

Date & Document Version	Changes Made	Summary of Changes
March 2009 v9.0.0	<ul style="list-style-type: none"> ■ Reorganized and updated information and terminology to clarify role of Nios II software build tools. ■ Corrected minor typographical errors. 	
May 2008 v8.0.0	No change from previous release.	
October 2007 v7.2.0	<ul style="list-style-type: none"> ■ Added documentation for MicroC/OS-II development with the Nios II software build tools. ■ Added description of HAL ISR support 	
May 2007 v7.1.0	<ul style="list-style-type: none"> ■ Added table of contents to Introduction section. ■ Added Referenced Documents section. 	
March 2007 v7.0.0	No change from previous release.	
November 2006 v6.1.0	No change from previous release.	
May 2006 v6.0.0	No change from previous release.	
October 2005 v5.1.0	No change from previous release.	
May 2005 v5.0.0	No change from previous release.	
December 2004 v1.1	Added thread-aware debugging paragraph.	
May 2004 v1.0	Initial Release.	