



## **Nios II Software Developer's Handbook**

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## Section I. Nios II Software Development

### Chapter 1. Overview

Introduction .....	1-1
Prerequisites .....	1-1
Finding Nios II EDS Files .....	1-1
Nios II Software Development Environment .....	1-2
Nios II EDS Development Flows .....	1-2
The Nios II Software Build Tools Development Flow .....	1-3
The Nios II IDE Development Flow .....	1-4
Nios II Programs .....	1-4
Makefiles and the Software Build Tools .....	1-4
Nios II Software Project Types .....	1-5
Altera Software Packages .....	1-5
Example Designs .....	1-6
Hardware Examples .....	1-6
Software Examples .....	1-6
Third-Party Support .....	1-7
Further Nios II Information .....	1-7
Referenced Documents .....	1-8
Document Revision History .....	1-8

### Chapter 2. Getting Started with the Graphical User Interface

Getting Started .....	2-1
The Nios II Software Build Tools for Eclipse Workbench .....	2-1
Creating a Project .....	2-2
Navigating the Project .....	2-4
Building the Project .....	2-4
Configuring the FPGA .....	2-5
Running the Project .....	2-5
Debugging the Project .....	2-6
Creating a Simple BSP .....	2-7
Makefiles and the Nios II Software Build Tools for Eclipse .....	2-8
Using the BSP Editor .....	2-9
Tcl Scripting and the Nios II BSP Editor .....	2-9
Starting the Nios II BSP Editor .....	2-9
The Nios II BSP Editor Screen Layout .....	2-9
The Command Area .....	2-10
The Console Area .....	2-13
Exporting a Tcl Script .....	2-14
Creating a New BSP .....	2-14
BSP Validation Errors .....	2-15
Configuring Component Search Paths .....	2-15
Run Configurations .....	2-15
The Project Tab .....	2-16
The Target Connection Tab .....	2-16
The Debugger Tab .....	2-16
Optimizing Project Build Time .....	2-16

Importing a Command-Line Project .....	2-17
Road Map .....	2-17
Import a Command-Line C/C++ Application .....	2-18
Import a Supporting Project .....	2-18
Programming Flash .....	2-19
Starting the Flash Programmer .....	2-19
Creating a Flash Programmer Settings File .....	2-19
The Flash Programmer Screen Layout .....	2-20
The Command Area .....	2-20
The Console Area .....	2-20
Saving a Flash Programmer Settings File .....	2-21
Flash Programmer Options .....	2-21
Creating an Internal Boot Memory Initialization File .....	2-22
Referenced Documents .....	2-22
Document Revision History .....	2-22

### Chapter 3. Getting Started from the Command Line

Introduction .....	3-1
Advantages of the Command Line .....	3-1
Outline of the Nios II Software Build Tools Command-Line Interface .....	3-1
Getting Started .....	3-3
What You Need .....	3-3
Creating hello_world for a Nios Development Board .....	3-3
Running hello_world on a Nios Development Board .....	3-4
Debugging hello_world .....	3-5
Scripting Basics .....	3-6
Creating a BSP with a Script .....	3-7
Creating an Application Project with a Script .....	3-9
<b>Running make</b> .....	<b>3-9</b>
Using the Nios II C2H Compiler .....	3-10
Referenced Documents .....	3-11
Document Revision History .....	3-12

### Chapter 4. Nios II Software Build Tools

Road Map for the Software Build Tools .....	4-2
What the Build Tools Create .....	4-2
Comparing the Command Line with Eclipse .....	4-2
Makefiles .....	4-3
Modifying Makefiles .....	4-3
Makefile Targets .....	4-4
Nios II Software Projects .....	4-4
Applications and Libraries .....	4-5
Board Support Packages .....	4-5
Software Build Process .....	4-7
Common BSP Tasks .....	4-8
Adding the Nios II Software Build Tools to Your Tool Flow .....	4-9
Linking and Locating .....	4-10
Other BSP Tasks .....	4-16
Details of BSP Creation .....	4-20
BSP Settings File Creation .....	4-22
Generated and Copied Files .....	4-22
HAL BSP Files and Folders .....	4-23
Linker Map Validation .....	4-26

Tcl Scripts for BSP Settings .....	4-26
Calling a Custom BSP Tcl Script .....	4-26
Revising Your BSP .....	4-29
Rebuilding Your BSP .....	4-29
Regenerating Your BSP .....	4-29
Updating Your BSP .....	4-31
Recreating Your BSP .....	4-32
Specifying BSP Defaults .....	4-34
Top Level Tcl Script for BSP Defaults .....	4-35
Specifying the Default stdio Device .....	4-36
Specifying the Default System Timer .....	4-36
Specifying the Default Memory Map .....	4-37
Specifying Default Bootloader Parameters .....	4-37
Using Individual Default Tcl Procedures .....	4-38
Device Drivers and Software Packages .....	4-38
Boot Configurations .....	4-38
Boot from Flash Configuration .....	4-39
Boot from Monitor Configuration .....	4-40
Run from Initialized Memory Configuration .....	4-40
Run-time Configurable Reset Configuration .....	4-41
Altera-Provided Development Tools .....	4-41
Nios II Software Build Tool GUIs .....	4-41
The Nios II Command-Line Commands .....	4-43
Restrictions .....	4-46
Referenced Documents .....	4-47
Document Revision History .....	4-47

## Section II. Hardware Abstraction Layer

### Chapter 5. Overview of the Hardware Abstraction Layer

Introduction .....	5-1
Getting Started .....	5-1
HAL Architecture .....	5-2
Services .....	5-2
Applications versus Drivers .....	5-3
Generic Device Models .....	5-3
C Standard Library—Newlib .....	5-4
Supported Hardware .....	5-4
Nios II Processor Core Support .....	5-4
Supported Peripherals .....	5-4
MPU Support .....	5-6
MMU Support .....	5-6
Referenced Documents .....	5-6
Document Revision History .....	5-7

### Chapter 6. Developing Programs Using the Hardware Abstraction Layer

Introduction .....	6-1
Nios II Development Flows .....	6-2
HAL BSP Settings .....	6-2
The Nios II Project Structure .....	6-2
The system.h System Description File .....	6-4
Data Widths and the HAL Type Definitions .....	6-5
UNIX-Style Interface .....	6-5

File System .....	6-6
Using Character-Mode Devices .....	6-8
Standard Input, Standard Output and Standard Error .....	6-8
General Access to Character Mode Devices .....	6-8
C++ Streams .....	6-9
/dev/null .....	6-9
Lightweight Character-Mode I/O .....	6-9
Altera Logging Functions .....	6-9
Using File Subsystems .....	6-15
Host-Based File System .....	6-15
Using Timer Devices .....	6-16
System Clock Driver .....	6-16
Alarms .....	6-17
Timestamp Driver .....	6-18
Using Flash Devices .....	6-19
Simple Flash Access .....	6-20
Block Erasure or Corruption .....	6-21
Fine-Grained Flash Access .....	6-21
Using DMA Devices .....	6-25
DMA Transmit Channels .....	6-26
DMA Receive Channels .....	6-27
Memory-to-Memory DMA Transactions .....	6-28
Using Interrupt Controllers .....	6-30
Reducing Code Footprint .....	6-30
Enable Compiler Optimizations .....	6-31
Use Reduced Device Drivers .....	6-31
Reduce the File Descriptor Pool .....	6-31
Use /dev/null .....	6-31
Use a Smaller File I/O Library .....	6-32
Use the Lightweight Device Driver API .....	6-34
Use the Minimal Character-Mode API .....	6-35
Eliminate Unused Device Drivers .....	6-36
Eliminate Unneeded Exit Code .....	6-36
Turn off C++ Support .....	6-36
Boot Sequence and Entry Point .....	6-37
Hosted versus Free-Standing Applications .....	6-37
Boot Sequence for HAL-Based Programs .....	6-37
Customizing the Boot Sequence .....	6-38
Memory Usage .....	6-39
Memory Sections .....	6-39
Assigning Code and Data to Memory Partitions .....	6-39
Placement of the Heap and Stack .....	6-42
Global Pointer Register .....	6-42
Boot Modes .....	6-44
Working with HAL Source Files .....	6-44
Finding HAL Files .....	6-44
Overriding HAL Functions .....	6-44
Referenced Documents .....	6-45
Document Revision History .....	6-45

## Chapter 7. Developing Device Drivers for the Hardware Abstraction Layer

Introduction .....	7-1
Integration in the HAL API .....	7-1
Peripheral-Specific API .....	7-2

Before You Begin .....	7-2
Development Flow for Creating Device Drivers .....	7-2
SOPC Builder Concepts .....	7-3
The Relationship between system.h and SOPC Builder .....	7-3
Using SOPC Builder for Optimal Hardware Configuration .....	7-3
Components, Devices, and Peripherals .....	7-3
Accessing Hardware .....	7-3
Creating Drivers for HAL Device Classes .....	7-5
Character-Mode Device Drivers .....	7-5
File Subsystem Drivers .....	7-8
Timer Device Drivers .....	7-8
Flash Device Drivers .....	7-9
DMA Device Drivers .....	7-10
Ethernet Device Drivers .....	7-12
Creating a Custom Device Driver for the HAL .....	7-15
Header Files and alt_sys_init.c .....	7-16
Device Driver Source Code .....	7-17
Integrating a Device Driver in the HAL .....	7-17
Overview .....	7-18
Assumptions and Requirements .....	7-18
The Nios II BSP Generator .....	7-19
File Names and Locations .....	7-20
Driver and Software Package Tcl Script Creation .....	7-21
Reducing Code Footprint .....	7-29
Provide Reduced Footprint Drivers .....	7-30
Support the Lightweight Device Driver API .....	7-30
Namespace Allocation .....	7-31
Overriding the Default Device Drivers .....	7-32
Referenced Documents .....	7-32
Document Revision History .....	7-33

## Section III. Advanced Programming Topics

### Chapter 8. Exception Handling

Introduction .....	8-1
Nios II Exception Handling Overview .....	8-1
Exception Handling Terminology .....	8-2
Interrupt Controllers .....	8-3
Latency and Response Time .....	8-5
How the Hardware Works .....	8-6
Interrupt Service Routines .....	8-7
HAL APIs for Hardware Interrupts .....	8-8
HAL ISR Restrictions .....	8-12
Writing an ISR .....	8-12
Registering an ISR with the Enhanced Interrupt API .....	8-14
Enabling and Disabling Interrupts .....	8-15
Configuring an External Interrupt Controller .....	8-16
C Example .....	8-16
Upgrading to the Enhanced HAL Interrupt API .....	8-18
Improving ISR Performance .....	8-18
Software Performance Improvements .....	8-18
Hardware Performance Improvements .....	8-23
Debugging ISRs .....	8-25

HAL Exception Handling System Implementation .....	8-26
Exception Handling System Structure .....	8-26
General Exception Funnel .....	8-27
Hardware Interrupt Funnel .....	8-27
Software Exception Funnel .....	8-29
Invalid Instructions .....	8-32
The Instruction-Related Exception Handler .....	8-32
Writing an Instruction-Related Exception Handler .....	8-33
Registering an Instruction-Related Exception Handler .....	8-34
Removing an Instruction-Related Exception Handler .....	8-35
Referenced Documents .....	8-35
Document Revision History .....	8-36

## Chapter 9. Cache and Tightly-Coupled Memory

Introduction .....	9-1
Nios II Cache Implementation .....	9-1
HAL API Functions for Managing Cache .....	9-2
Further Information .....	9-2
Initializing Cache after Reset .....	9-2
For HAL Users .....	9-3
Writing Device Drivers .....	9-4
For HAL Users .....	9-4
Writing Program Loaders or Self-Modifying Code .....	9-5
For Users of the HAL .....	9-5
Managing Cache in Multi-Master/ Multi-Processor Systems .....	9-5
Bit-31 Cache Bypass .....	9-6
For HAL Users .....	9-6
Tightly-Coupled Memory .....	9-7
Referenced Documents .....	9-7
Document Revision History .....	9-7

## Chapter 10. MicroC/OS-II Real-Time Operating System

Introduction .....	10-1
Overview .....	10-1
Further Information .....	10-1
Licensing .....	10-2
Other RTOS Providers .....	10-2
The Nios II Implementation of MicroC/OS-II .....	10-2
MicroC/OS-II Architecture .....	10-2
MicroC/OS-II Thread-Aware Debugging .....	10-3
MicroC/OS-II Device Drivers .....	10-3
Thread-Safe HAL Drivers .....	10-4
The Newlib ANSI C Standard Library .....	10-5
Interrupt Service Routines for MicroC/OS-II .....	10-6
Implementing MicroC/OS-II Projects for the Nios II Processor .....	10-6
Referenced Documents .....	10-6
Document Revision History .....	10-7

## Chapter 11. Ethernet and the NicheStack TCP/IP Stack - Nios II Edition

Overview .....	11-1
Prerequisites .....	11-2
Introduction .....	11-2
The NicheStack TCP/IP Stack Files and Directories .....	11-3



Licensing .....	11-3
Other TCP/IP Stack Providers .....	11-3
Using the NicheStack TCP/IP Stack .....	11-3
Nios II System Requirements .....	11-4
The NicheStack TCP/IP Stack Tasks .....	11-4
Initializing the Stack .....	11-4
Calling the Sockets Interface .....	11-7
Configuring the NicheStack TCP/IP Stack in a Nios II Program .....	11-9
NicheStack TCP/IP Stack General Settings .....	11-9
IP Options .....	11-10
TCP Options .....	11-10
Further Information .....	11-10
Known Limitations .....	11-10
Referenced Documents .....	11-11
Document Revision History .....	11-11

## Chapter 12. Read-Only Zip File System

Introduction .....	12-1
Using the Zip File System in a Project .....	12-1
Preparing the Zip File .....	12-1
Programming the Zip File to Flash .....	12-2
Referenced Documents .....	12-2
Document Revision History .....	12-2

## Chapter 13. Publishing Component Information to Embedded Software

Component Information Flow .....	13-1
Embedded Software Assignments .....	13-2
C Macro Namespace .....	13-2
Configuration Namespace .....	13-3
Memory Initialization Namespace .....	13-6
Referenced Documents .....	13-7
Document Revision History .....	13-7

## Section IV. Reference Material

### Chapter 14. HAL API Reference

Introduction .....	14-1
HAL API Functions .....	14-1
Standard Types .....	14-80
Referenced Documents .....	14-80
Document Revision History .....	14-80

### Chapter 15. Nios II Software Build Tools Reference

Introduction .....	15-1
Nios II Software Build Tools Utilities .....	15-1
Logging Levels .....	15-2
Setting Values .....	15-2
Utility and Script Summary .....	15-2
nios2-app-generate-makefile .....	15-3
nios2-bsp-create-settings .....	15-5
nios2-bsp-generate-files .....	15-6
nios2-bsp-query-settings .....	15-7

nios2-bsp-update-settings	15-8
nios2-lib-generate-makefile	15-10
nios2-bsp-editor	15-11
nios2-app-update-makefile	15-12
nios2-lib-update-makefile	15-14
nios2-swexample-create	15-17
nios2-elf-insert	15-17
nios2-elf-query	15-18
nios2-convert-ide2sbt	15-19
nios2-flash-programmer-generate	15-19
nios2-c2h-generate-makefile	15-22
nios2-bsp	15-23
Nios II Example Design Scripts	15-24
create-this-bsp	15-25
create-this-app	15-26
Finding create-this-app and create-this-bsp	15-26
Settings	15-27
Overview of BSP Settings	15-28
Overview of Component and Driver Settings	15-28
Settings Reference	15-29
Application and User Library Makefile Variables	15-65
Application Makefile Variables	15-65
User Library Makefile Variables	15-67
Standard Build Flag Variables	15-67
Tcl Commands	15-68
Tcl Command Environments	15-68
Tcl Commands for BSP Settings	15-68
Tcl Commands for BSP Generation Callbacks	15-89
Tcl Commands for Drivers and Packages	15-97
Path Names	15-106
Command Arguments	15-107
Object File Directory Tree	15-108
Referenced Documents	15-109
Document Revision History	15-109

## Appendix A. Using the Nios II Integrated Development Environment

Introduction	A-1
The Nios II IDE Tools	A-1
Differences from the Nios II Software Build Tools	A-1
Nios II IDE Makefiles	A-2
Nios II IDE Terminology	A-2
Altera Nios II Instruction Set Simulator	A-3
Command-Line Tools	A-3
Getting Started with the Nios II IDE	A-4
The Nios II IDE Workbench	A-4
EDS Development Flows and the Nios II IDE	A-4
Creating a New Nios II IDE-Managed Project	A-5
Building and Managing Projects	A-6
Running and Debugging Programs	A-6
Programming Flash	A-7
Developing Software with the Nios II IDE	A-7
Using the HAL in an IDE Project	A-7
Device Drivers for Nios II IDE Projects	A-9
Exception Handling in a Nios II IDE Project	A-11

---

Configuring MicroC/OS-II Projects with the Nios II IDE .....	A-12
Using NicheStack in a Nios II IDE Project .....	A-17
Porting Nios II IDE Projects to the Software Build Tools .....	A-18
Converting a Nios II IDE Project .....	A-18
Other Software Modules .....	A-19
Using Your Converted Project .....	A-20
Archiving Nios II IDE Software Projects .....	A-21
Required Files .....	A-21
File Write Permissions .....	A-22
Help System .....	A-22
Referenced Documents .....	A-22
Document Revision History .....	A-23

## Additional Information

How to Find Further Information .....	Info-1
How to Contact Altera .....	Info-1
Typographic Conventions .....	Info-2



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## Section I. Nios II Software Development

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This section introduces Nios® II software development, including the available tools and tool flows.

This section includes the following chapters:

- [Chapter 1, Overview](#)
- [Chapter 2, Getting Started with the Graphical User Interface](#)
- [Chapter 3, Getting Started from the Command Line](#)
- [Chapter 4, Nios II Software Build Tools](#)





## Introduction

The *Nios® II Software Developer's Handbook* provides the basic information needed to develop software for the Altera® Nios II processor. This handbook describes the Nios II software development environment, the Nios II Embedded Design Suite (EDS) tools available to you, and the process for developing software.

This chapter provides a high-level overview of the software development environments for the Nios II processor, and contains the following sections:

- “Nios II Software Development Environment” on page 1–2
- “Nios II EDS Development Flows” on page 1–2
- “Nios II Programs” on page 1–4
- “Altera Software Packages” on page 1–5
- “Example Designs” on page 1–6
- “Third-Party Support” on page 1–7
- “Further Nios II Information” on page 1–7

## Prerequisites

The *Nios II Software Developer's Handbook* assumes you have a basic familiarity with embedded processor concepts. You do not need to be familiar with any specific Altera technology or with Altera development tools. Familiarity with Altera hardware development tools can give you a deeper understanding of the reasoning behind the Nios II software development environment. However, software developers can create and debug applications without further knowledge of Altera technology.

## Finding Nios II EDS Files

When you install the Nios II EDS, you specify a root directory for the EDS file structure. For example, if the Nios II EDS 9.1 is installed on the Windows operating system, the root directory might be `c:\altera\91\nios2eds`.

The root directory can be any accessible location in your file system. For simplicity, this handbook refers to this directory as *<Nios II EDS install path>*.



The Nios II EDS defines the environment variable `SOPC_KIT_NIOS2` to represent *<Nios II EDS install path>*.

## Nios II Software Development Environment

The Nios II EDS provides a consistent software development environment that works for all Nios II processor systems. With the Nios II EDS running on a host computer, an Altera FPGA, and a JTAG download cable (such as an Altera USB-Blaster™ download cable), you can write programs for and communicate with any Nios II processor system. The Nios II processor's JTAG debug module provides a single, consistent method to connect to the processor using a JTAG download cable. Accessing the processor is the same, regardless of whether a device implements only a Nios II processor system, or whether the Nios II processor is embedded deeply in a complex multiprocessor system. Therefore, you do not need to spend time manually creating interface mechanisms for the embedded processor.

The Nios II EDS includes proprietary and open-source tools (such as the GNU C/C++ tool chain) for creating Nios II programs. The Nios II EDS automates board support package (BSP) creation for Nios II processor-based systems, eliminating the need to spend time manually creating BSPs. The BSP provides a C/C++ runtime environment, insulating you from the hardware in your embedded system. Altera BSPs contain the Altera hardware abstraction layer (HAL), an optional RTOS, and device drivers.

## Nios II EDS Development Flows

A development flow is a way of using a set of development tools together to create a software project. The Nios II EDS provides the following development flows for creating Nios II programs:

- The Nios II Software Build Tools, which provide two user interfaces:
  - The Nios II Software Build Tools command line
  - The Nios II Software Build Tools for Eclipse™
- The Nios II integrated development environment (IDE)

The two design flows share a number of development tools. However, the flows differ markedly in how they create makefiles. The development flows are not interchangeable. Source code for your applications, libraries, and drivers works in either flow, but the makefiles in the two flows are different and not compatible.



The future direction of Nios II software development support is toward the Software Build Tools and away from the Nios II IDE. The Nios II EDS provides a tool for converting Nios II IDE projects to Software Build Tools projects.



For details about Nios II IDE project conversion, refer to “Porting Nios II IDE Projects to the Software Build Tools” in *Appendix A. Using the Nios II Integrated Development Environment* in the *Nios II Software Developer's Handbook*.



Hardware designs created with SOPC Builder 7.0 or earlier must either use the Nios II IDE development flow or be updated.

## The Nios II Software Build Tools Development Flow

The Nios II Software Build Tools allow you to create Nios II software projects, with detailed control over the software build process. The same Nios II Software Build Tools utilities, scripts and Tcl commands are available from both the command line and Nios II Software Build Tools for Eclipse™ graphical user interface (GUI).

The Software Build Tools allow you to create and manage single-threaded programs as well as complex applications based on an RTOS and middleware libraries available from Altera and third-party vendors.

The Software Build Tools provide powerful Tcl scripting capabilities. In a Tcl script, you can query project settings, specify project settings conditionally, and incorporate the software project creation process in a scripted software development flow. Tcl scripting is supported both in Eclipse and at the command line.



For information about Tcl scripting, refer to the *Nios II Software Build Tools* chapter of the *Nios II Software Developer's Handbook*.

### The Nios II Software Build Tools for Eclipse

The Nios II Software Build Tools for Eclipse is a thin GUI layer that runs the Nios II Software Build Tools utilities and scripts behind the scenes, presenting a unified development environment. The Software Build Tools for Eclipse provide a consistent development platform that works for all Nios II processor systems. You can accomplish all software development tasks within Eclipse, including creating, editing, building, running, debugging, and profiling programs.

The Nios II Software Build Tools for Eclipse are based on the popular Eclipse™ framework and the Eclipse C/C++ development toolkit (CDT) plugins. The Nios II Software Build Tools create your project makefiles for you, and Eclipse provides extensive capabilities for interactive debugging and management of source files.

The Software Build Tools for Eclipse also allow you to import and debug projects you created in the Nios II Command Shell.



For details about the Nios II Software Build Tools for Eclipse, refer to the *Getting Started with the Graphical User Interface* chapter of the *Nios II Software Developer's Handbook*. For details about Eclipse, visit the Eclipse Foundation website ([www.eclipse.org](http://www.eclipse.org)).

### The Nios II Software Build Tools Command Line

In the Nios II Software Build Tools command line development flow, you create, modify, build, and run Nios II programs with Nios II Software Build Tools commands typed at a command line or embedded in a script. You run the Nios II Software Build Tools commands from the Nios II Command Shell.



For further information about the Nios II Software Build Tools in command-line mode, refer to the *Getting Started from the Command Line* chapter of the *Nios II Software Developer's Handbook*.

To debug your command-line program, import your Software Build Tools projects to Eclipse. You can further edit, rebuild, run, and debug your imported project in Eclipse.

## The Nios II IDE Development Flow

The Nios II IDE development flow is an integrated environment in which you can create, modify, build, run, and debug Nios II programs with the Nios II IDE GUI. The Nios II IDE flow does not use the Nios II Software Build Tools. The makefiles it creates cannot be user-managed. This flow provides limited control over the build process and the project settings, with no support for customized scripting.



In most cases, you should create new projects using the Nios II Software Build Tools from the command line or from Eclipse. The IDE will be discontinued in a future release. IDE support is for the following situations:

- Working with pre-existing Nios II IDE software projects
- Creating new projects for the Nios II C2H compiler
- Debugging with the FS2 console



For further information about the Nios II IDE, refer to *Appendix A. Using the Nios II Integrated Development Environment* in the *Nios II Software Developer's Handbook*.

The remainder of this handbook assumes that you are using the Nios II Software Build Tools.

## Nios II Programs

Each Nios II program you develop consists of an application project, optional user library projects, and a BSP project. You build your Nios II program to create an Executable and Linking Format File (**.elf**) which runs on a Nios II processor.

The Nios II Software Build Tools create software projects for you. Each project is based on a makefile. This section discusses makefiles and projects.

## Makefiles and the Software Build Tools

The makefile is the central component of a Nios II software project, whether the project is created with the Nios II Software Build Tools for Eclipse, or on the command line. The makefile describes all the components of a software project and how they are compiled and linked. With a makefile and a complete set of C/C++ source files, your Nios II software project is fully defined.

As a key part of creating a software project, the Software Build Tools create a makefile for you. Nios II projects are sometimes called “user-managed,” because you, the user, are responsible for the content of the project makefile. You use the Nios II Software Build Tools to control what goes in the makefile.



Makefiles for Nios II IDE projects differ from the Software Build Tools makefiles described in this section.



The *Nios II Software Build Tools* chapter of the *Nios II Software Developer's Handbook* provides detailed information about creating makefiles. For a description of Nios II IDE makefiles, refer to *Appendix A. Using the Nios II Integrated Development Environment* in the *Nios II Software Developer's Handbook*.

## Nios II Software Project Types

The following sections describe the project types that constitute a Nios II program.

### Application Project

A Nios II C/C++ application project consists of a collection of source code, plus a makefile. A typical characteristic of an application is that one of the source files contains function `main()`. An application includes code that calls functions in libraries and BSPs. The makefile compiles the source code and links it with a BSP and one or more optional libraries, to create one `.elf` file.

### User Library Project

A user library project is a collection of source code compiled to create a single library archive file (`.a`). Libraries often contain reusable, general purpose functions that multiple application projects can share. A collection of common arithmetical functions is one example. A user library does not contain a `main()` function.

### BSP Project

A Nios II BSP project is a specialized library containing system-specific support code. A BSP provides a software runtime environment customized for one processor in an SOPC Builder system. The Nios II EDS provides tools to modify settings that control the behavior of the BSP.

A BSP contains the following elements:

- Hardware abstraction layer—For information, refer to the *Overview of the Hardware Abstraction Layer* chapter of the *Nios II Software Developer's Handbook*.
- Newlib C standard library—For information, refer to the *Overview of the Hardware Abstraction Layer* chapter of the *Nios II Software Developer's Handbook*. The complete HTML documentation for newlib resides in the Nios II EDS directory.
- Device drivers—For information, refer to “Nios II Software Projects” in the *Nios II Software Build Tools* chapter of the *Nios II Software Developer's Handbook*.
- Optional software packages—For information, refer to “Altera Software Packages”.
- Optional real-time operating system—For information, refer to the *MicroC/OS-II Real-Time Operating System* chapter of the *Nios II Software Developer's Handbook*.

## Altera Software Packages

The Nios II EDS includes software packages to extend the capabilities of your software. You can include these software packages in your BSP. [Table 1-1](#) shows the Altera Nios II software packages.

**Table 1-1.** Software Packages

Name	Description
NicheStack TCP/IP Stack - Nios II Edition	Refer to the <i>Ethernet and the NicheStack TCP/IP Stack - Nios II Edition</i> chapter of the <i>Nios II Software Developer's Handbook</i> .
Read-only zip file system	Refer to the <i>Read-Only Zip File System</i> chapter of the <i>Nios II Software Developer's Handbook</i> .
Host file system	Refer to the <i>Developing Programs Using the Hardware Abstraction Layer</i> chapter of the <i>Nios II Software Developer's Handbook</i> .

## Example Designs

The Nios II EDS includes documented hardware example designs and software examples to demonstrate all prominent features of the Nios II processor and the development environment. The examples can be very helpful as you start the development of your custom design. They provide a stable starting point for exploring design options. Also, they demonstrate many commonly used features of the Nios II EDS.

## Hardware Examples

You can run Nios II hardware designs on many Nios development boards. The hardware examples for each Nios II development board reside in the following location:

`<Nios II EDS install path>/examples/<language>/<board>`

`<language>` is either **vhdl** or **verilog** and `<board>` is the name of the development board. For example, the Triple Speed Ethernet Verilog HDL example design for the Nios II 3C120 development board resides in `<Nios II EDS install path>/examples/verilog/niosII_cycloneIII_3c120/triple_speed_ethernet_design`.

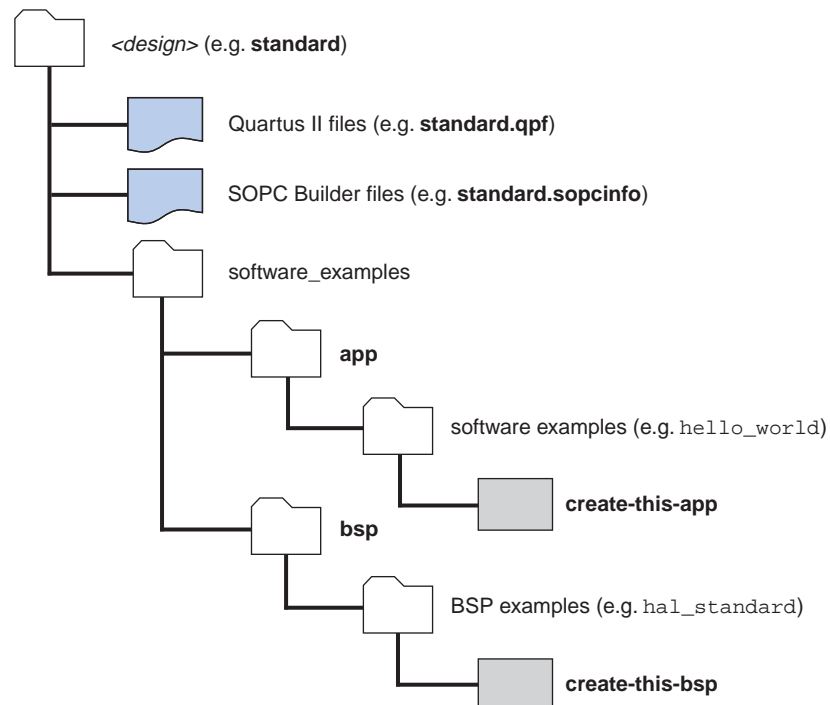
## Software Examples

You can run Nios II software examples that run on many of the hardware example designs described in the previous section.

The Nios II software examples include scripts and templates to create the software projects using the Nios II Software Build Tools. These scripts and templates do everything necessary to create a BSP and an application project for each software example.

**Figure 1-1** shows the directory structure under each hardware example design. There are multiple software examples and BSP examples, each with its own directory. Each software example directory contains a **create-this-app** script and each BSP example directory contains a **create-this-bsp** script. These scripts create software projects, as demonstrated in “Getting Started” in the *Getting Started from the Command Line* chapter of the *Nios II Software Developer's Handbook*.

**Figure 1-1.** Software Example Design Directory Structure



## Third-Party Support

Several third-party vendors support the Nios II processor, providing products such as design services, operating systems, stacks, other software libraries, and development tools.



For the most up-to-date information about third-party support for the Nios II processor, visit the [Nios II Processor](#) page of the Altera website.

## Further Nios II Information

This handbook is one part of the complete Nios II processor documentation suite. Consult the following references for further Nios II information:

- The *Nios II Processor Reference Handbook* defines the processor hardware architecture and features, including the instruction set architecture.
- *Volume 5: Embedded Peripherals* of the *Quartus II Handbook* provides a reference for the peripherals distributed with the Nios II processor. This handbook describes the hardware structure and Nios II software drivers for each peripheral.
- The *Embedded Design Handbook* describes how to use Altera software development tools effectively, and recommends design styles and practices for developing, debugging, and optimizing embedded systems.
- The Altera Knowledge Database is an Internet resource that offers solutions to frequently asked questions with an easy-to-use search engine. Visit the [Knowledge Database](#) page of the Altera website.



- Altera application notes and tutorials offer step-by-step instructions on using the Nios II processor for a specific application or purpose. These documents are available on the [Literature: Nios II Processor](#) page of the Altera website.
- The Nios II EDS documentation launchpad. The launchpad is an HTML page installed with the Nios II EDS, which provides links to Nios II documentation, examples, and other resources. The way you open the launchpad depends on your software platform.
  - In the Windows operating system, on the Start menu, point to **Programs > Altera > Nios II EDS**, and click **Nios II <version> Documentation**.
  - In the Linux operating system, open `<Nios II EDS install path>/documents/index.html` in a web browser.

## Referenced Documents

This chapter references the following documents:

- *Getting Started with the Graphical User Interface* chapter of the *Nios II Software Developer's Handbook*
- *Getting Started from the Command Line* chapter of the *Nios II Software Developer's Handbook*
- *Nios II Software Build Tools* chapter of the *Nios II Software Developer's Handbook*
- *Overview of the Hardware Abstraction Layer* chapter of the *Nios II Software Developer's Handbook*
- *Developing Programs Using the Hardware Abstraction Layer* chapter of the *Nios II Software Developer's Handbook*
- *MicroC/OS-II Real-Time Operating System* chapter of the *Nios II Software Developer's Handbook*
- *Ethernet and the NicheStack TCP/IP Stack - Nios II Edition* chapter of the *Nios II Software Developer's Handbook*
- *Read-Only Zip File System* chapter of the *Nios II Software Developer's Handbook*
- *Appendix A. Using the Nios II Integrated Development Environment* in the *Nios II Software Developer's Handbook*
- *Nios II Processor Reference Handbook*
- *Embedded Design Handbook*
- *Volume 5: Embedded Peripherals* of the *Quartus II Handbook*
- GNU HTML documentation, available at the [Nios II Embedded Design Suite Support](#) page of the Altera website.
- The [Nios II Processor](#) page of the Altera website.
- The [Literature: Nios II Processor](#) page of the Altera website.

## Document Revision History

Table 1-2 shows the revision history for this document.



**Table 1–2.** Document Revision History

Date & Document Version	Changes Made	Summary of Changes
November 2009 v9.1.0	<ul style="list-style-type: none"> <li>■ Described the Nios II Software Build Tools for Eclipse</li> <li>■ Nios II IDE information moved to <i>Appendix A. Using the Nios II Integrated Development Environment</i></li> <li>■ Detailed Nios II Software Build Tools utility information moved to <i>Nios II Software Build Tools</i></li> </ul>	<ul style="list-style-type: none"> <li>■ Introduction of the Nios II Software Build Tools for Eclipse</li> </ul>
March 2009 v9.0.0	<ul style="list-style-type: none"> <li>■ Incorporate information formerly in <i>Altera-Provided Development Tools</i> chapter.</li> <li>■ Describe BSP Editor.</li> <li>■ Reorganize and update information and terminology to clarify role of Nios II Software Build Tools.</li> <li>■ Describe <code>-data</code> argument for IDE command-line tools.</li> <li>■ Correct minor typographical errors.</li> </ul>	<ul style="list-style-type: none"> <li>■ List of development tools</li> <li>■ BSP Editor</li> </ul>
May 2008 v8.0.0	Add “What’s New” section.	<ul style="list-style-type: none"> <li>■ SOPC Information File (<b>.sopcinfo</b>)</li> <li>■ Example designs removed from EDS</li> <li>■ Memory management unit (MMU) added to Nios II core</li> </ul>
October 2007 v7.2.0	No change from previous release.	
May 2007 v7.1.0	<ul style="list-style-type: none"> <li>■ Revise entire chapter to introduce Nios II EDS design flows, Nios II programs, Nios II Software Build Tools, and Nios II BSPs.</li> <li>■ Add table of contents to Introduction section.</li> <li>■ Add “Referenced Documents” section.</li> </ul>	Nios II Software Build Tools
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.	
May 2004 v1.0	Initial Release.	



The Nios® II Software Build Tools for Eclipse™ are a set of plugins based on the popular Eclipse™ framework and the Eclipse C/C++ development toolkit (CDT) plugins. The Nios II Software Build Tools for Eclipse provide a consistent development platform that works for all Nios II processor systems. You can accomplish all Nios II software development tasks within Eclipse, including creating, editing, building, running, debugging, and profiling programs.

This chapter familiarizes you with the features of the Nios II Software Build Tools for Eclipse. This chapter contains the following sections:

- “Getting Started”
- “Makefiles and the Nios II Software Build Tools for Eclipse” on page 2–8
- “Using the BSP Editor” on page 2–9
- “Run Configurations” on page 2–15
- “Optimizing Project Build Time” on page 2–16
- “Importing a Command-Line Project” on page 2–17
- “Programming Flash” on page 2–19

### Getting Started

Writing software for the Nios II processor is similar to writing software for any other microcontroller family. The easiest way to start designing effectively is to purchase a development kit from Altera that includes documentation, a ready-made evaluation board, a getting-started reference design, and all the development tools necessary to write Nios II programs.

Modifying existing code is a common, easy way to learn to start writing software in a new environment. The Nios II Embedded Design Suite (EDS) provides many example software designs that you can examine, modify, and use in your own programs. The provided examples range from a simple “Hello world” program, to a working RTOS example, to a full TCP/IP stack running a web server. Each example is documented and ready to compile.

This section guides you through the most fundamental operations in the Nios II Software Build Tools for Eclipse in a tutorial-like fashion. It shows how to create an application project for the Nios II processor, along with the board support package (BSP) project required to interface with your hardware. It also shows how to build the application and BSP projects in Eclipse, and how to run the software on a Nios development board.

### The Nios II Software Build Tools for Eclipse Workbench

The term “workbench” refers to the Nios II Software Build Tools for Eclipse desktop development environment. The workbench is where you edit, compile and debug your programs in Eclipse.

## Perspectives, Editors, and Views

Each workbench window contains one or more perspectives. Each perspective provides a set of capabilities for accomplishing a specific type of task.

Most perspectives in the workbench comprise an editor area and one or more views. An editor allows you to open and edit a project resource (i.e., a file, folder, or project). Views support editors, and provide alternative presentations and ways to navigate the information in your workbench.

Any number of editors can be open at once, but only one can be active at a time. The main menu bar and toolbar for the workbench window contain operations that are applicable to the active editor. Tabs in the editor area indicate the names of resources that are currently open for editing. An asterisk (\*) indicates that an editor has unsaved changes. Views can also provide their own menus and toolbars, which, if present, appear along the top edge of the view. To open the menu for a view, click the drop-down arrow icon at the right of the view's toolbar or right-click in the view. A view might appear on its own, or stacked with other views in a tabbed notebook.



For detailed information about the Eclipse workbench, perspectives, and views, refer to the Eclipse help system.



Before you create a Nios II project, you must ensure that the Nios II perspective is visible. To open the Nios II perspective, on the Window menu, point to **Open Perspective**, then **Other**, and click **Nios II**.

## Creating a Project

In the Nios II perspective, on the File menu, point to **Nios II Application and BSP from Template**. The **Nios II Application and BSP from Template** wizard appears. This wizard provides a quick way to create an application and BSP at the same time.



Alternatively, you can create separate application, BSP and user library projects.

### Specifying the Application

In the first page of the **Nios II Application and BSP from Template** wizard, you specify a hardware platform, a project name, and a project template. You optionally override the default location for the application project, and specify a processor name if you are targeting a multiprocessor hardware platform.

You specify a BSP in the second page of the wizard.

### Specifying the Hardware Platform

You specify the target hardware design by selecting a SOPC Information File (.sopcinfo) in the **SOPC Information File name** box.

### Specifying the Project Name

Select a descriptive name for your project. The Software Build Tools create a folder with this name to contain the application project files.



Letters, numbers, and the underscore (\_) symbol are the only valid project name characters. Project names cannot contain spaces or special characters. The first character in the project name must be a letter or underscore. The maximum filename length is 250 characters.

The Software Build Tools also create a folder to contain BSP project files, as described in [“Specifying the BSP”](#).

### Specifying the Project Template

Project templates are ready-made, working software projects that serve as examples to show you how to structure your own Nios II projects. It is often easier to start with a working project than to start a blank project from scratch.

You select the project template from the **Templates** list.



The `hello_world` template provides an easy way to create your first Nios II project and verify that it builds and runs correctly.

### Specifying the Project Location

The project location is the parent directory in which the Software Build Tools create the project folder. By default, the project location is under the directory containing the `.sopcinfo` file, in a folder named **software**.

To place your application project in a different folder, turn off **Use default location**, and specify the path in the **Project location** box.

### Specifying the Processor

If your target hardware contains multiple Nios II processors, **CPU name** contains a list of all available processors in your design. Select the processor on which your software is intended to run.

### Specifying the BSP

When you have finished specifying the application project in the first page of the **Nios II Application and BSP from Template** wizard, you proceed to the second page by clicking **Next**.

On the second page, you specify the BSP to link with your application. You can create a new BSP for your application, or select an existing BSP. Creating a new BSP is often the simplest way to get a project running the first time.

You optionally specify the name and location of the BSP.

### Specifying the BSP Project Name

By default, if your application project name is `<project>`, the BSP is named `<project>_bsp`. You can type in a different name if you prefer. The Software Build Tools create a directory with this name, to contain the BSP project files. BSP project names are subject to the same restrictions as application project names, as described in [“Specifying the Project Name”](#).

### Specifying the BSP Project Location

The BSP project location is the parent directory in which the Software Build Tools create the folder. The default project location is the same as the default location for an application project. To place your BSP in a different folder, turn off **Use default location**, and specify the BSP location in the **Project location** box.

### Selecting an Existing BSP

As an alternative to creating a BSP automatically from a template, you can associate your application project with a pre-existing BSP. Select **Select an existing BSP project from your workspace**, and select a BSP in the list. The **Create** and **Import** buttons to the right of the existing BSP list provide convenient ways to add BSPs to the list.

### Creating the Projects

When you have specified your BSP, you click **Finish** to create the projects. The Software Build Tools copy required source files to your project directories, and create makefiles and other generated files. Finally, the Software Build Tools execute a **make clean** command on your BSP.



For details about what happens when Nios II projects are created, refer to “Nios II Software Projects” in the *Nios II Software Build Tools* chapter of the *Nios II Software Developer’s Handbook*. For details about the **make clean** command, refer to “Makefiles” in the same chapter.

## Navigating the Project

When you have created a Nios II project, it appears in the **Project Explorer** view, which is typically displayed at the left side of the Nios II perspective. You can expand each project to examine its folders and files.



For an explanation of the folders and files in a Nios II BSP, refer to “Nios II Software Projects” in the *Nios II Software Build Tools* chapter of the *Nios II Software Developer’s Handbook*.

## Building the Project

To build a Nios II project in the Nios II Software Build Tools for Eclipse, right-click the project name and click **Build Project**. A progress bar shows you the build status. The build process can take a minute or two for a simple project, depending on the speed of the host machine. Building a complex project takes longer.

During the build process, you view the build commands and command-line output in the Eclipse **Console** view.



For details about Nios II Software Build Tools commands and output, refer to the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer’s Handbook*.

When the build process is complete, the following message appears in the **Console** view:

```
[<project name> build complete]
```

If the project has a dependency on another project, such as a BSP or a user library, the Software Build Tools build the dependency project first. This feature allows you to build an application and its BSP with a single command.

## Configuring the FPGA

Before you can run your software, you must ensure that the correct hardware design is running on the FPGA. To configure the FPGA, you use the Quartus® II Programmer.

In the Windows operating system, you start the Quartus II Programmer from the Nios II Software Build Tools for Eclipse, through the Nios II menu. In the Linux operating system, you start Quartus II Programmer from the Quartus II software.

The project directory for your hardware design contains an SRAM Object File (.sof) along with the .sopcinfo file. The .sof file contains the hardware design to be programmed in the FPGA.



For details about programming an FPGA with Quartus II Programmer, refer to the *Quartus II Programmer* chapter in *Volume 3: Verification of the Quartus II Handbook*.

## Running the Project

This section describes how to run a Nios II program using the Nios II Software Build Tools for Eclipse. You can run a Nios II program on Nios II hardware, such as a Nios development board, or under Nios II ModelSim®.



A separate Nios II instruction set simulator is also available through the Lauterbach GmbH website ([www.lauterbach.com](http://www.lauterbach.com)).

To run a software project, right-click the application project name, point to **Run As**, and click **Nios II Hardware** or **Nios II ModelSim**. This command carries out the following actions:

- Creates a Nios II run configuration. For details about run configurations, refer to “Run Configurations” on page 2-15.
- Builds the project executable. If all target files are up to date, nothing is built.
- If debugging on hardware, establishes communications with the target, and verifies that the FPGA is configured with the correct hardware design.
- Downloads the Executable and Linking Format File (.elf) to the target memory
- Starts execution at the .elf entry point.

Program output appears in the Console view of Eclipse. The Console view maintains a terminal I/O connection with a communication device connected to the Nios II processor in the SOPC Builder system, such as a JTAG UART. When the Nios II program writes to `stdout` or `stderr`, the Console view displays the text. The Console view can also accept character input from the host keyboard, which is sent to the processor and read as `stdin`.

To disconnect the terminal from the target, click the **Terminate** icon in the Console view. Terminating only disconnects the host from the target. The target processor continues executing the program.

## Debugging the Project

This section describes how to debug a Nios II program using the Nios II Software Build Tools for Eclipse. You can debug a Nios II program on Nios II hardware, such as a Nios development board, or under Nios II ModelSim.

To debug a software project, right-click the application project name, point to **Debug As**, and click **Nios II Hardware** or **Nios II ModelSim**. This command carries out the following actions:

- Creates a Nios II run configuration. For details about run configurations, refer to [“Run Configurations” on page 2-15](#).
- Builds the project executable. If all target files are up to date, nothing is built.
- If debugging on hardware, establishes communications with the target, and verifies that the FPGA is configured with the correct hardware design.
- Downloads the **.elf** to the target memory.
- Sets a breakpoint at the top of `main ( )`.
- Starts execution at the **.elf** entry point.

The Eclipse debugger with the Nios II plugins provides a Nios II perspective, allowing you to perform many common debugging tasks. Debugging a Nios II program with the Nios II plugins is generally the same as debugging any other C/C++ program with Eclipse and the CDT plugins.



For information about debugging with Eclipse and the CDT plugins, refer to the Eclipse help system.

The debugging tasks you can perform with the Nios II Software Build Tools for Eclipse include the following tasks:

- Controlling program execution with commands such as:
  - Suspend (pause)
  - Resume
  - Terminate
  - Step Into
  - Step Over
  - Step Return
- Setting breakpoints and watchpoints
- Viewing disassembly
- Instruction stepping mode
- Displaying and changing the values of local and global variables in the following formats:
  - Binary
  - Decimal
  - Hexadecimal



- Displaying watch expressions
- Viewing and editing registers in the following formats:
  - Binary
  - Decimal
  - Hexadecimal
- Viewing and editing memory in the following formats:
  - Hexadecimal
  - ASCII
  - Signed integer
  - Unsigned integer

Just as when running a program, Eclipse displays program output in the Console view of Eclipse. The Console view maintains a terminal I/O connection with a communication device connected to the Nios II processor in the SOPC Builder system, such as a JTAG UART. When the Nios II program writes to stdout or stderr, the Console view displays the text. The Console view can also accept character input from the host keyboard, which is sent to the processor and read as stdin.

To disconnect the terminal from the target, click the **Terminate** icon in the Console view. Terminating only disconnects the host from the target. The target processor continues executing the program.

## Creating a Simple BSP

You create a BSP with default settings using the **Nios II Board Support Package** wizard. To start the wizard, on the File menu, point to **New** and click **Nios II Board Support Package**.

The **Nios II Board Support Package** wizard enables you to specify the following BSP parameters:

- The name
- The underlying SOPC Builder design
- The location
- The operating system



You can select the operating system only at the time you create the BSP. To change operating systems, you must create a new BSP.

- Additional arguments to the **nios2-bsp** script



For details about **nios2-bsp** command arguments, refer to “Details of BSP Creation” in the *Nios II Software Build Tools* chapter of the *Nios II Software Developer’s Handbook*.

After you have created the BSP, you have the following options for GUI-based BSP editing:

- To access and modify basic BSP properties, right-click the BSP project, point to Properties and click Nios II BSP Properties.
- To modify parameters and settings in detail, use the Nios II BSP Editor, described in [“Using the BSP Editor”](#).

## Makefiles and the Nios II Software Build Tools for Eclipse

Nios II Software Build Tools for Eclipse create and manage the makefiles for Nios II software projects. When you create a project, the Nios II Software Build Tools create a makefile based on parameters and setting you select. When you modify parameters and settings, the Nios II Software Build Tools update the makefile to match.

Nios II BSP makefiles are handled differently from application and user library makefiles. BSP makefiles are based on the operating system, BSP settings, selected software packages, and selected drivers.



For further details on specifying BSPs, refer to [“Using the BSP Editor”](#) on page 2-9.

Nios II application and user library makefiles are based on source files and properties that you specify directly. You can examine and modify many makefile properties in the **Nios II Application Properties** or **Nios II Library Properties** dialog box. To open the dialog box, right-click the project, click **Properties**, and click **Nios II Application Properties** or **Nios II Library Properties**.

[Table 2-1](#) lists actions that make changes to an application or user library makefile.

**Table 2-1.** Actions that Modify an Application or User Library Makefile

Specifying the application or user library name <a href="#">(1)</a>
Adding or removing source files <a href="#">(2)</a>
Specifying a path to an associated BSP <a href="#">(3)</a>
Specifying a path to an associated user library <a href="#">(3)</a>
Enabling, disabling or modifying compiler options <a href="#">(1)</a>

**Notes to [Table 2-1](#):**

- (1) Modified in the **Nios II Application Properties** or **Nios II Library Properties** dialog box.
- (2) For details about adding and removing project source files in Eclipse, refer to the Eclipse help system.
- (3) Modified in the **Project References** dialog box. To open the dialog box, right-click the project, point to **Properties**, and click **Project References**.

After the Software Build Tools have created a makefile, you can modify the makefile in any of the following ways:

- With the Nios II Software Build Tools for Eclipse, as described in [Table 2-1](#).
- With Nios II Software Build Tools commands from the Nios II Command Shell.
- Manually, with a text editor.



Editing a makefile manually is an advanced technique. Altera recommends that you avoid manual editing. The Software Build Tools provide extensive editing capabilities, and ensure makefile correctness.

When modifying a makefile, the Software Build Tools preserve any previous modifications, regardless how those modifications were made.



When the Nios II Software Build Tools for Eclipse modify a makefile, they lock the makefile to prevent corruption by other processes. You cannot edit the makefile from the command line until the Software Build Tools have removed the lock.

You can remove a makefile from source management control through the **Nios II Application Properties** or **Nios II Library Properties** dialog box. Simply turn off **Enable source file management** to convert the makefile to a unmanaged makefile. You must manually keep your makefile updated to reflect source files added to or removed from the project.

## Using the BSP Editor

Typically, you create a BSP with the Nios II Software Build Tools for Eclipse. The Nios II plugins provide the basic tools and settings for defining your BSP. For more advanced BSP editing, use the Nios II BSP Editor. The BSP Editor provides all the tools you need to create even the most complex BSPs.

### Tcl Scripting and the Nios II BSP Editor

The Nios II BSP Editor provides support for Tcl scripting. When you create a BSP in the BSP Editor, the editor can run a Tcl script that you specify to supply BSP settings.

You can also export a Tcl script from the BSP Editor, containing all the settings in an existing BSP. By studying such a script, you can learn about how BSP Tcl scripts are constructed.

### Starting the Nios II BSP Editor

You start the Nios II BSP Editor in one of the following ways:

- Right-click an existing project, point to **Nios II**, and click **BSP Editor**. The editor loads the BSP Settings File (**.bsp**) associated with your project, and is ready to update it.
- On the Nios II menu, click **Nios II BSP Editor**. The editor starts without loading a **.bsp** file.
- Right-click an existing BSP project and click **Properties**. In the **Properties** dialog box, select **Nios II BSP Properties**, and click **BSP Editor**. The editor loads your **.bsp** file for update.

### The Nios II BSP Editor Screen Layout

The Nios II BSP Editor screen is divided into two areas. The top area is the command area, and the bottom is the console area. The details of the Nios II BSP Editor screen areas are described in this section.

Below the console area is the **Generate** button. This button is enabled when the BSP settings are valid. It generates the BSP target files, as shown in the **Target Generation Files** tab.

## The Command Area

In the command area, you specify settings and other parameters defining the BSP. The command area contains several tabs:

- The **Settings** tab
- The **Software Packages** tab
- The **Drivers** tab
- The **Linker Script** tab
- The **Target Generation Files** tab

Each tab allows you to view and edit a particular part of the **.bsp**, along with relevant command line parameters and Tcl scripts.



The settings that appear on the **Settings**, **Software Packages** and **Drivers** tabs are the same as the settings you manipulate on the command line.



For detailed descriptions of settings defined for Altera-provided operating systems, software packages, and drivers, refer to the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*.

### The Settings Tab

The **Settings** tab presents general settings and parameters, and operating system settings, for the BSP. The BSP includes the following settings and parameters:

- The path to the **.sopcinfo** file specifying the target hardware
- The processor name
- The operating system



You cannot change the operating system in an existing BSP. You must create a new BSP based on the desired operating system.

- The BSP target directory—the destination for files that the Software Build Tools copy and create for your BSP.
- BSP settings

BSP settings appear in a tree structure. Settings are organized into Common and Advanced categories. Settings are further organized into functional groups. The available settings depend on the operating system.

When you select a group of settings, the controls for those settings appear in the pane to the right of the tree. When you select a single setting, the pane shows the setting control, the full setting name, and the setting description.

Software package and driver settings are presented separately, as described in “[The Software Packages Tab](#)” and “[The Drivers Tab](#)”.

### The Software Packages Tab

The **Software Packages** tab allows you to insert and remove software packages in your BSP, and control software package settings.

At the top of the **Software Packages** tab is the software package table, listing each available software package. The table allows you to select the software package version, and enable or disable the software package.



The operating system determines which software packages are available.

Many software packages define settings that you can control in your BSP. When you enable a software package, the available settings appear in a tree structure, organized into Common and Advanced settings.

When you select a group of settings, the controls for those settings appear in the pane to the right of the tree. When you select a single setting, the pane shows the setting control, the full setting name, and the setting description.



Enabling and disabling software packages and editing software package settings can have a profound impact on BSP behavior. Refer to the documentation for the specific software package for details. For the read-only zip file system, refer to the *Read-Only Zip File System* chapter of the *Nios II Software Developer's Handbook*. For the NicheStack TCP/IP Stack - Nios II Edition, refer to the *Ethernet and the NicheStack TCP/IP Stack - Nios II Edition* chapter of the *Nios II Software Developer's Handbook*.

General settings, operating system settings, and driver settings are presented separately, as described in “*The Settings Tab*” and “*The Drivers Tab*”.

## The Drivers Tab

The **Drivers** tab allows you to select, enable, and disable drivers for devices in your system, and control driver settings.

At the top of the **Drivers** tab is the driver table, mapping each component in the SOPC Builder system to a driver. Each component has a module name, module version, module class name, driver name, and driver version, determined by the contents of the SOPC Builder system. The table allows you to select the driver by name and version, as well as to enable or disable each driver.



When you select a driver version, all instances of that driver in the BSP are set to the version you select. Only one version of a given driver can be used in an individual BSP.

Many drivers define settings that you can control in your BSP. Available driver settings appear in a tree structure below the driver table, organized into Common and Advanced settings.

When you select a group of settings, the controls for those settings appear in the pane to the right of the tree. When you select a single setting, the pane shows the setting control, the full setting name, and the setting description.



Enabling and disabling device drivers, changing drivers and driver versions, and editing driver settings, can have a profound impact on BSP behavior. Refer to the relevant component documentation and driver information for details. For Altera® components, refer to *Volume 5: Embedded Peripherals* of the *Quartus II Handbook*.

General settings, operating system settings, and software package settings are presented separately, as described in “[The Settings Tab](#)” and “[The Software Packages Tab](#)”.

### The Linker Script Tab

The **Linker Script** tab allows you to view available memory in your SOPC Builder system, and examine and modify the arrangement and usage of linker regions in memory.

When you make a change to the memory configuration, the Software Build Tools validate your change. If there is a problem, a message appears in the **Problems** tab in the console area, as described in “[The Problems Tab](#)” on page 2-13.



Rearranging linker regions and linker section mappings can have a profound impact on BSP behavior.

### Linker Regions

At the top of the **Linker Script** tab, the linker region table shows all defined linker regions. Each row of the table shows one linker region, with its address range, memory device name, size, and offset into the selected memory device.

You reassign a defined linker region to a different memory device by selecting a different device name in the **Memory Device Name** column. The **Size** and **Offset** columns are editable. You can also carry out the following actions with buttons located next to the linker region table:

- Add a linker region—The **Add** button allows you to add a linker region in unused space on any existing device. The **Add** button opens the **Add Memory Region** dialog box, where you specify the memory device, the new memory region name, the region size, and the region’s offset from the device base address.
- Restore default linker regions—The **Restore Defaults** button restores the memory regions to the default configuration set up when the BSP was created.
- View Memory Device Usage Table—The **Memory Usage** button opens the **Memory Device Usage Table**. The **Memory Device Usage Table** allows you to view memory device usage by defined memory region. As memory regions are added, removed, and adjusted, each device's free memory, used memory, and percentage of available memory are updated. The rightmost column is a graphical representation of the device’s usage, according to the memory regions assigned to it.
- View Memory Map—The **Memory Map** button opens the **Memory Map** dialog box. The memory map allows you to view a map of system memory in the processor address space. The **Device** table is a read-only reference showing memories in the SOPC Builder system that are mastered by the selected processor. Devices are listed in memory address order.

To the right of the **Device** table is a graphical representation of the processor’s memory space, showing the locations of devices in the table. Gaps indicate unmapped address space.



This representation is not to scale.

### Linker Section Mappings

Below the linker region table is the linker section table, showing the mapping from linker sections to linker regions. You can edit the BSP linker section mappings by carrying out the following actions with buttons located next to the linker section table:

- Add a linker section mapping—The **Add** button allows you to add a linker section mapping to an existing linker region. The **Add** button opens the **Add Section Mapping** dialog box, where you specify a new section name and an existing linker region.
- Restore default linker sections—The **Restore Defaults** button restores the section mappings to the default configuration set up when the BSP was created.

### Target Generation Files Tab

The **Target Generation Files** tab shows, in tree form, the organization of the target files to be generated for the BSP. It does not depict the actual file system, but rather the files and directories to be created or copied when the BSP is generated. Each software component, including the operating system, drivers, and software packages, specifies source code to be copied into the BSP target directory. The files are generated in the directory specified on the **Settings** tab.

You cannot edit the file destinations shown in the **Target Generation Files** tab. It is a read-only reference showing you what output to expect when the BSP is generated.



When you generate the BSP, existing BSP files are overwritten.

## The Console Area

The console area shows results of settings and commands that you select in the command area. The console area consists of the following tabs:

- The **Information** tab
- The **Problems** tab
- The **Processing** tab

The following sections describe each tab.

### The Information Tab

The **Information** tab shows a running list of high-level changes you make to your BSP, such as adding a software package or changing a setting value.

### The Problems Tab

The **Problems** tab shows warnings and errors that impact or prohibit BSP creation. For example, if you inadvertently specify an invalid linker section mapping, a message appears in the **Problems** tab.

### The Processing Tab

When you generate your BSP, the **Processing** tab shows files and folders created and copied in the BSP target directory.

## Exporting a Tcl Script

When you have configured your BSP to your satisfaction, you can export the BSP settings as a Tcl script. This feature allows you to perform the following tasks:

- Regenerate the BSP from the command line
- Recreate the BSP as a starting point for a new BSP
- Recreate the BSP on a different hardware platform
- Examine the Tcl script to improve your understanding of Tcl command usage

The exported Tcl script captures all nondefault settings in the BSP.

To export a Tcl script, in the Tools menu, click **Export Tcl Script**, and specify a filename and destination path. The file extension is **.tcl**.



To import a Tcl script during BSP creation, refer to “[Using an Imported Tcl Script](#)”. For details about default BSP settings, refer to “Tcl Scripts for BSP Settings” in the *Nios II Software Build Tools* chapter of the *Nios II Software Developer’s Handbook*.

## Creating a New BSP

To create a BSP in the Nios II BSP Editor, use the **New BSP** command in the File menu to open the **New BSP Setting File** dialog box. This dialog box controls the creation of a new BSP settings file. The BSP Editor loads this new BSP after the file is created.

In this dialog box, you specify the following parameters:

- The name of the BSP settings file. It is created with file extension **.bsp**.
- The operating system.



You can select the operating system only at the time you create the BSP. To change operating systems, you must create a new BSP.

- A Tcl script to import, for additional settings.
- The **.sopcinfo** file defining the hardware platform.



Normally, the path to your **.sopcinfo** file should be specified relative to the BSP directory. This enables you to move, copy and archive the hardware and software files together. If you browse to the **.sopcinfo** file, or specify an absolute path, the Nios II BSP Editor offers to convert your path to the relative form.


### Using an Imported Tcl Script

When you create a BSP, the **New BSP Settings File** dialog box allows you to specify the path and filename of a Tcl script. The Nios II BSP Editor imports this script and runs it to specify BSP settings. This feature allows you to perform the following tasks:

- Recreate an existing BSP as a starting point for a new BSP
- Recreate a BSP on a different hardware platform
- Include custom settings common to a group of BSPs

The Tcl script can be created by hand, or exported from another BSP.




 “Exporting a Tcl Script” describes how to create a Tcl script from an existing BSP. Refer to “Tcl Scripts for BSP Settings” in the *Nios II Software Build Tools* chapter of the *Nios II Software Developer’s Handbook* for further information about creating Tcl scripts.

## BSP Validation Errors

If you modify an SOPC Builder system after basing a BSP on it, some BSP settings might no longer be valid. This is a very common cause of BSP validation errors.

In general, if you modify the underlying hardware design, the best practice is to create a new BSP. Creating a BSP is very easy with the Software Build Tools. Manually correcting a large number of interrelated settings, on the other hand, can be difficult.

When you need to create a new BSP, you might find it helpful to capture your old BSP settings by exporting them to a Tcl script. You can edit the Tcl script to remove any settings that are incompatible with the new hardware design.

 For details about exporting and importing Tcl scripts, refer to “Exporting a Tcl Script” and “Using an Imported Tcl Script”. For a detailed discussion of updating BSPs for modified SOPC Builder systems, refer to “Revising Your BSP” in the *Nios II Software Build Tools* chapter of the *Nios II Software Developer’s Handbook*.

## Configuring Component Search Paths

By default, the Software Build Tools discover system components using the same search algorithm as SOPC Builder. You can define additional search paths to be used for locating components.

You define additional search paths through the **Edit Custom Search Paths** dialog box. In the Tools menu, click **Options**, select **BSP Component Search Paths**, and click **Custom Component Search Paths**. You can specify multiple search paths. Each path can be recursive.

## Run Configurations

Eclipse uses run configurations to control how it runs and debugs programs. Run configurations in the Nios II Software Build Tools for Eclipse have several features that help you debug Nios II software running on FPGA platforms.

You can open the run configuration dialog box two ways:

- You can right-click an application, point to **Run As**, and click **Run Configurations**.
- You can right-click an application, point to **Debug As**, and click **Debug Configurations**.

Depending on which way you opened the run configuration dialog box, the title is either **Run Configuration** or **Debug Configuration**. However, both views show the same run configurations.

Each run configuration is presented in several tabs. This section describes each tab.

## The Project Tab

On this tab, you specify the application project to run. The **Advanced** button opens the **Nios II ELF Section Properties** dialog box. In this dialog box, you can control the runtime parameters in the following ways:

- Specify the processor on which to execute the program (if the hardware design provides multiple processors)
- Specify the device to use for standard I/O
- Specify the expected location, timestamp and value of the system ID
- Specify the path to the Quartus II JTAG Debugging Information File (.jdi)
- Enable or disable profiling



The Nios II Software Build Tools for Eclipse set these parameters to reasonable defaults. Do not modify them unless you have a clear understanding of their effects.

## The Target Connection Tab

This tab allows you to control the connection between the host machine and the target hardware in the following ways:

- Select the cable, if more than one cable is available
- Allow software to run despite a system ID value or timestamp that differs from the hardware
- Reset the processor when the software is downloaded

The **System ID Properties** button allows you to examine the system ID and timestamp in both the .elf file and the hardware. This can be helpful when you need to analyze the cause of a system ID or timestamp mismatch.

## The Debugger Tab

In this tab, you optionally enable the debugger to halt at a specified entry point.

## Optimizing Project Build Time

When you build a Nios II project, the project makefile builds any components that are unbuilt or out of date. For this reason, the first time you build a project is normally the slowest. Subsequent builds are fast, only rebuilding sources that have changed.

To further optimize your project build time, disable generation of the objdump linker map.



Nios II software build performance is generally better on Linux platforms than on Windows platforms.

## Importing a Command-Line Project

If you have software projects that were created with the Nios II Software Build Tools command line, you can import the projects into the Nios II Software Build Tools for Eclipse for debugging and further development. This section discusses the import process.

Your command-line C/C++ application, and its associated BSP, might be created on the command line, or converted from a Nios II IDE project. Regardless of its origin, any Nios II Software Build Tools command-line project is ready to import into the Nios II Software Build Tools for Eclipse. No additional preparation is necessary.

The Nios II Software Build Tools for Eclipse imports several kinds of Nios II command-line projects:

- Command-line C/C++ application project
- Command-line BSP project
- Command-line user library project

You can edit, build, debug, and manage the settings of an imported project exactly the same way you edit, build, debug, and manage the settings of a project created in Nios II Software Build Tools for Eclipse.

The Nios II Software Build Tools for Eclipse import each type of project through the **Import** wizard. The **Import** wizard determines the kind of project you are importing, and configures it appropriately.

You can continue to develop project code in your Software Build Tools project after importing the project into Eclipse. You can edit source files and rebuild the project, using the Software Build Tools either in Eclipse or on the command line.



Nios II Integrated Development Environment (IDE) projects cannot be directly imported to the Software Build Tools for Eclipse. You must first convert the project for use with the Software Build Tools, by following to the procedures in [Appendix A. Using the Nios II Integrated Development Environment](#) in the *Nios II Software Developer's Handbook*.



For further information about creating projects with the command line, refer to the [Getting Started from the Command Line](#) chapter of the *Nios II Software Developer's Handbook*.

## Road Map

Importing and debugging a project typically involves several of the following tasks. You do not need to perform these tasks in this order, and you can repeat or omit some tasks, depending on your needs.

- Import a command-line C/C++ application
- Import a supporting project
- Debug a command-line C/C++ application
- Edit command-line C/C++ application code

You debug and edit an imported project exactly the same way you debug and edit a project created in Eclipse. The following sections describe importing command-line projects.



When you import a command-line project, the Nios II Software Build Tools for Eclipse give you the option of converting your makefile to a fully managed makefile. Accept this option if all your project source files are located under the project folder. However, if any project source files are outside the project folder, do not convert to a managed makefile. You must manually keep your makefile updated to reflect source files added to or removed from the project.

## Import a Command-Line C/C++ Application

To import a command-line C/C++ application, perform the following steps:

1. Start the Nios II Software Build Tools for Eclipse.
2. On the File menu, click **Import**. The **Import** dialog box appears.
3. Expand the **Software Build Tools Project** folder, and select **Import Nios II project**.
4. Click **Next**. The **File Import** wizard appears.
5. Click **Browse** and locate the directory containing the C/C++ application project to import.
6. Click **OK**. The wizard fills in the project path.
7. Specify the project name in the **Project name** box.



You might see a warning saying “There is already a **.project** file at: *<path>*”. This warning indicates that the directory already contains an Eclipse project. Either it is an Eclipse project, or it is a command-line project that is already imported into Eclipse.

If the project is already in your workspace, do not re-import it.

8. Click **Finish**. The wizard imports the application project.

At this point, the Nios II Software Build Tools for Eclipse can build, debug, and run the complete program, including the BSP and any libraries, by using the Software Build Tools makefiles in your imported C/C++ application project. Eclipse can display and step through application source code, exactly as if the project were created in the Nios II Software Build Tools for Eclipse. However, Eclipse does not have direct information about where BSP or user library code resides. If you need to view, debug or step through BSP or user library source code, you need to import the BSP or user library. The process of importing supporting projects, such as BSPs and libraries, is described in the next section.

## Import a Supporting Project

While debugging a C/C++ application, you might need to view, debug or step through source code in a supporting project, such as a BSP or user library. To make supporting project source code visible in the Eclipse debug perspective, you need to import the supporting project.

If you do not need BSP or user library source code visible in the debugger, you can skip this task, and proceed to debug your project exactly as if you had created it in Eclipse.



If you have several C/C++ applications based on one BSP or user library, import the BSP or user library once, and then import each application that is based on the BSP or user library. Each application's makefile contains the information needed to find and build any associated BSP or libraries.

The steps for importing a supporting project are exactly the same as those shown in ["Import a Command-Line C/C++ Application"](#).

## Programming Flash

Many Nios II processor systems use external flash memory to store one or more of the following items:

- Program code
- Program data
- FPGA configuration data
- File systems

The Nios II Software Build Tools for Eclipse provide flash programmer utilities to help you manage and program the contents of flash memory. The flash programmer allows you to program any combination of software, hardware, and binary data into flash memory in one operation.

## Starting the Flash Programmer

You start the flash programmer by clicking **Flash Programmer** in the Nios II menu.

When you first open the flash programmer, no controls are available until you open or create a Flash Programmer Settings File (**.flash-settings**).

## Creating a Flash Programmer Settings File

The **.flash-settings** file describes how you set up the flash programmer graphical user interface (GUI) to program flash. This information includes the files to be programmed to flash, an SOPC Builder system describing the hardware configuration, and the file programming locations. You must create or open a flash programmer settings file before you can program flash.

You create a flash programmer settings file through the File menu. When you click **New**, the **New Flash Programmer Settings File** dialog box appears.

### Specifying the Hardware Configuration

You specify the hardware configuration by opening a **.sopcinfo** file. You can locate the **.sopcinfo** file in either of two ways:

- Browse to a BSP settings file. The flash programmer finds the **.sopcinfo** file associated with the BSP.
- Browse directly to a **.sopcinfo** file.

Once you have identified a hardware configuration, details about the target hardware appear at the top of the Nios II flash programmer screen.

Also at the top of the Nios II flash programmer screen is the **Hardware Connections** button, which opens the **Hardware Connections** dialog box. This dialog box allows you to select a download cable, and control system ID behavior, as described in “[The Target Connection Tab](#)” on page 2-16.

## The Flash Programmer Screen Layout

The flash programmer screen is divided into two areas. The top area is the command area, and the bottom is the console area. The details of the flash programmer screen areas are described in this section.

Below the console area is the **Start** button. This button is enabled when the flash programmer parameters are valid. It starts the process of programming flash.

### The Command Area

In the command area, you specify settings and other parameters defining the flash programmer settings file. The command area contains one or more tabs. Each tab represents a flash memory component available in the target hardware. Each tab allows you to view the parameters of the memory component, and view and edit the list of files to be programmed in the component.

The **Add** and **Remove** buttons allow you to create and edit the list of files to be programmed in the flash memory component.

The **File generation command** box shows the commands used to generate the Motorola S-record Files (**.flash**) used to program flash memory.

The **File programming command** box shows the commands used to program the **.flash** files to flash memory.

The **Properties** button opens the **Properties** dialog box, which allows you to view and modify information about an individual file. In the case of a **.elf**, the **Properties** button provides access to the project reset address, the flash base and end addresses, and the boot loader file (if any).



The flash programmer determines whether a boot loader is required based on the load and run locations of the **.text** section. You can use the **Properties** dialog box to override the default boot loader configuration.

### The Console Area

The console area shows results of settings and commands that you select in the command area. The console area consists of several tabs:

- The **Information** tab
- The **Problems** tab
- The **Processing** tab

This section describes each tab.

### The Information Tab

The **Information** tab shows the high-level changes you make to your flash programmer settings file.

### The Problems Tab

The **Problems** tab shows warnings and error messages about the process of flash programmer settings file creation.

### The Processing Tab

When you program flash, the **Processing** tab shows the individual programming actions as they take place.

## Saving a Flash Programmer Settings File

When you have finished configuring the input files, locations, and other settings for programming your project to flash, you can save the settings in a **.flash-settings** file. With a **.flash-settings** file, you can program the project again without reconfiguring the settings. You save a **.flash-settings** file through the File menu.

## Flash Programmer Options

Through the Options menu, you can control several global aspects of flash programmer behavior, as described in this section.



For details about these features, refer to the *Nios II Flash Programmer User's Guide*.

### Staging Directories

Through the **Staging Directories** dialog box, you control where the flash programmer creates its script and **.flash-settings** files.

### Generate Files

If you disable this option, the flash programmer does not generate programming files, but programs files already present in the directory. You might use this feature to reprogram a set of files that you have previously created.

### Program Files

If you disable this option, the flash programmer generates the programming files and the script, but does not program flash. You can use the files later to program flash by turning off the **Generate Files** option.

### Erase Flash Before Programming

When enabled, this option erases flash memory before programming.

### Run From Reset After Programming

When enabled, this option resets and starts the Nios II processor after programming flash.

## Creating an Internal Boot Memory Initialization File

The Nios II Software Build Tools for Eclipse can create a Hexadecimal (Intel-Format) File (.hex), required to boot the Nios II directly from internal memory without downloading. To create a .hex file for your project, right-click the application project, point to **Make Targets**, and click **Build** to open the **Make Targets** dialog box. Select and build the mem\_init\_install target.

The mem\_init\_install target creates a file called <memory component name>.hex, and places it in your Quartus project directory. After creating the .hex file, recompile your Quartus project.



For more information about creating memory initialization files, refer to “Common BSP Tasks” in the *Nios II Software Build Tools* chapter of the *Nios II Software Developer’s Handbook*.

## Referenced Documents

This chapter references the following documents:

- *Getting Started from the Command Line* chapter of the *Nios II Software Developer’s Handbook*
- *Nios II Software Build Tools* chapter of the *Nios II Software Developer’s Handbook*
- *Ethernet and the NicheStack TCP/IP Stack - Nios II Edition* chapter of the *Nios II Software Developer’s Handbook*
- *Read-Only Zip File System* chapter of the *Nios II Software Developer’s Handbook*
- *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer’s Handbook*
- *Appendix A. Using the Nios II Integrated Development Environment* in the *Nios II Software Developer’s Handbook*
- *Quartus II Programmer* chapter in *Volume 3: Verification of the Quartus II Handbook*
- *Volume 5: Embedded Peripherals* of the *Quartus II Handbook*
- *Nios II Flash Programmer User’s Guide*

## Document Revision History

The following table displays the revision history for this document.

Date & Document Version	Changes Made	Summary of Changes
November 2009 v9.1.0	Initial release.	—



## Introduction

The Nios II Software Build Tools allow you to construct a wide variety of complex software systems using a command-line interface. From this interface, you can execute Software Built Tools command utilities, and use scripts (or other tools) to combine the command utilities in many useful ways.

This chapter introduces you to project creation with the Software Build Tools at the command line.

This chapter includes the following sections:

- “Getting Started”
- “Scripting Basics” on page 3–6
- “Running make”
- “Using the Nios II C2H Compiler” on page 3–10

## Advantages of the Command Line

The Nios II Software Build Tools command line offers the following advantages over the Nios II Software Build Tools for Eclipse:

- You can invoke the command line tools from custom scripts or other tools that you might already use in your development flow
- On a command line, you can run several Tcl scripts to control the creation of a board support package (BSP).
- You can use command line tools in a bash script to build several projects at once.

The Nios II Software Build Tools command-line interface is designed to work in the Nios II Command Shell.



For details about the Nios II Command Shell, refer to “The Nios II Command Shell” on page 3–3.

## Outline of the Nios II Software Build Tools Command-Line Interface

The Nios II Software Build Tools command-line interface consists of:

- Command-line utilities
- Command-line scripts
- Tcl commands
- Tcl scripts

These elements work together in the Nios II Command Shell to create software projects.

## Utilities

The Nios II Software Build Tools command-line utilities enable you to create software projects. You can call these utilities from the command line or from a scripting language of your choice (such as **perl** or **bash**). On Windows, these utilities have a **.exe** extension. The Nios II Software Build Tools reside in the **sdk2/bin** directory under *<Nios II EDS install path>*.



In the Nios II Command Shell, *<Nios II EDS install path>* is specified by the **SOPC\_KIT\_NIOS2** environment variable.



Refer to “Altera-Provided Development Tools” in the *Nios II Software Build Tools* chapter of the *Nios II Software Developer’s Handbook* for a summary of the command-line utilities provided by the Nios II Software Build Tools.

## Scripts

Nios II Software Build Tools scripts implement complex behavior that extends the capabilities provided by the utilities.

**Table 3–1** summarizes the scripts provided with the Nios II Software Build Tools.

**Table 3–1.** Nios II Software Build Tools Scripts

Command	Summary
<b>nios2-bsp</b>	Creates or updates a BSP
<b>create-this-app</b> (1)	Creates a software example and builds it
<b>create-this-bsp</b> (1)	Creates a BSP for a specific hardware example design and builds it
<b>nios2-c2h-generate-makefile</b>	Creates an application makefile fragment for the Nios II C2H Compiler. (2)

**Note to Table 3–1:**

- (1) There are **create-this-app** scripts for each software example and several **create-this-bsp** scripts for each hardware example design. For more details, refer to “Nios II Example Design Scripts” in the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer’s Handbook*.
- (2) The **nios2-c2h-generate-makefile** script is available to support pre-existing command-line C2H projects. Create new C2H projects using the Nios II Integrated Development Environment (IDE).

## Tcl Commands

Tcl commands are a crucial component of the Nios II Software Build Tools. Tcl commands allow you to exercise detailed control over BSP generation, as well as to define drivers and software packages.

## Tcl Scripts

The Software Build Tools provide powerful Tcl scripting capabilities. In a Tcl script, you can query project settings, specify project settings conditionally, and incorporate the software project creation process in a scripted software development flow. The Software Build Tools use Tcl scripting to customize your BSP according to your hardware and the settings you select. You can also write custom Tcl scripts for detailed control over the BSP.

## The Nios II Command Shell

The Nios II Command Shell is a **bash** command-line environment initialized with the correct settings to run Nios II command-line tools. To open the Nios II Command Shell, execute the following steps, depending on your environment:

- In the Windows operating system, on the Start menu, point to **Programs > Altera > Nios II EDS**, and click **Nios II Command Shell**.
- In the Linux operating system, in a command shell, execute the following commands:

```
cd $SOPC_KIT_NIOS2↵  
./sdk_shell↵
```

## Getting Started

Using the Nios II Software Build Tools on the command line is the best way to learn about them. The following tutorial guides you through the process of creating, building, running, and debugging a “Hello World” program with a minimal number of steps. Later chapters provide more of the underlying details, allowing you to take more control of the process. The goal of this chapter is to show you that the basic process is simple and straightforward.

The Nios II Software Build Tools include a number of scripts that demonstrate how to combine command utilities to obtain the results you need. This tutorial uses a **create-this-app** script as an example.

## What You Need

To complete this tutorial, you must have the following:

- Altera® Quartus® II development software, version 8.0 or later. The software must be installed on a Windows or Linux computer that meets the Quartus II minimum requirements.
- The Altera Nios II Embedded Design Suite (EDS), version 8.0 or later.
- A Nios development board.
- A download cable such as the Altera USB-Blaster™ cable.

You run the Nios II Software Build Tools commands from the Nios II Command Shell.



For details about the Nios II Command Shell, refer to [“The Nios II Command Shell”](#).

## Creating hello\_world for a Nios Development Board

In this section you create a simple “Hello World” project. To create and build the `hello_world` example for a Nios development board, perform the following steps:

1. Start the Nios II Command Shell, as described in [“The Nios II Command Shell”](#).
2. Create a working directory for your hardware and software projects. The following steps refer to this directory as `<projects>`.
3. Change to the `<projects>` directory by typing the following command:

```
cd <projects>↵
```

4. Locate a Nios II hardware example for your Nios development board. For example, if you have a Cyclone® II development board, you might select `<Nios II EDS install path>/examples/verilog/niosII_cycloneII_2c35/standard`.

This example uses the Verilog HDL standard hardware example design. You can select the language you prefer (Verilog HDL or VHDL), and any type of example design except `small`.

5. Copy the hardware example to your `<projects>` working directory, using a command such as the following:

```
cp -R $SOPC_KIT_NIOS2/examples/verilog/niosII_cycloneII_2c35/standard .
```

6. Ensure that the working directory and all subdirectories are writable by typing the following command:

```
chmod -R +w .
```

7. The `<projects>` directory contains a subdirectory named **software\_examples/app/hello\_world**. The following steps refer to this directory as `<application>`.

8. Change to the `<application>` directory by typing the following command:

```
cd <application>
```

9. Type the following command to create and build the application:

```
./create-this-app
```

The **create-this-app** script copies the application source code to the `<application>` directory, runs **nios2-app-generate-makefile** to create a makefile (named **Makefile**), and then runs **make** to create an Executable and Linking Format File (**.elf**). The **create-this-app** script finds a compatible BSP by looking in `<projects>/software_examples/bsp`. In the case of `hello_world`, it selects the `hal_default` BSP.

To create the example BSP, **create-this-app** calls the **create-this-bsp** script in the BSP directory.

## Running hello\_world on a Nios Development Board

To run the `hello_world` example on a Nios development board, perform the following steps:

1. Start the Nios II Command Shell.
2. Download the SRAM Object File (**.sof**) for the Quartus II project to the Nios development board. This step configures the FPGA on the development board with your project's associated SOPC Builder system.

The **.sof** file resides in `<projects>`, along with your Quartus II Project File (**.qpf**). You download it by typing the following commands:

```
cd <projects>
nios2-configure-sof
```

The board is configured and ready to run the project's executable code.

The **nios2-configure-sof** utility runs the Quartus II Programmer to download the **.sof** file. You can also run the `quartus_pgm` command directly.



For more information about programming the hardware, refer to the *Nios II Hardware Development Tutorial*.

3. Start another command shell. If practical, make both command shells visible on your desktop.
4. In the second command shell, run the Nios II terminal application to connect to the Nios development board through the JTAG UART port by typing the following command:

```
nios2-terminal ↵
```

5. Return to the original command shell, and ensure that `<projects>/software_examples/app/hello_world` is the current working directory.
6. Download and run the `hello_world` executable program as follows:

```
nios2-download -g hello_world.elf ↵
```

The following output appears in the second command shell:

```
Hello from Nios II!
```

## Debugging hello\_world

An integrated development environment is the most powerful environment for debugging a software project. You debug a command-line project by importing it to the Nios II Software Build Tools for Eclipse. After you import the project, Eclipse uses your makefiles to build the project. This two-step process combines the advantages of the Software Build Tools command line development flow with the convenience of a graphical user interface (GUI) debugger.

This section discusses the process of importing and debugging the **hello\_world** application.


### Import the hello\_world Application

To import the **hello\_world** application, perform the following steps:

1. Launch the Nios II Software Build Tools for Eclipse.
2. On the File menu, click **Import**. The **Import** dialog box appears.
3. Expand the **Nios II Project** folder, and select **Import Nios II project**.
4. Click **Next**. The **File Import** wizard appears.
5. Click **Browse** and navigate to the `<application>` directory, containing the **hello\_world** application project.
6. Click **OK**. The wizard fills in the project path.
7. Type the project name `hello_world` in the **Project name** box.
8. Click **Finish**. The wizard imports the application project.



If you want to view the BSP source files while debugging, you also need to import the BSP project into the Nios II Software Build Tools for Eclipse.

 For a description of importing BSPs into Eclipse, refer to “Importing a Command-Line Project” in the *Getting Started with the Graphical User Interface* chapter of the *Nios II Software Developer’s Handbook*.

### Download Executable Code and Start the Debugger

To debug the software project, perform the following steps:

1. Right-click the `hello_world` project, point to **Debug As**, and click **Nios II Hardware**.
2. If the **Confirm Perspective Switch** dialog box appears, click **Yes**.

After a moment, you see the `main()` function in the editor. There is a blue arrow next to the first line of code, indicating that execution is stopped on this line.

When targeting Nios II hardware, the **Debug As** command does the following tasks:

- Creates a default debug configuration for the target board.
  - Establishes communication with the target board
  - Optionally verifies that the expected SOPC Builder system is configured in the FPGA.
  - Downloads the `.elf` file to memory on the target board.
  - Sets a breakpoint at `main()`.
  - Instructs the Nios II processor to begin executing the code.
3. In the Run menu, click **Resume** to resume execution. You can also resume execution by pressing **F8**.

When debugging a project in Eclipse, you can also pause, stop, and single-step the program, set breakpoints, examine variables, and perform many other common debugging tasks.

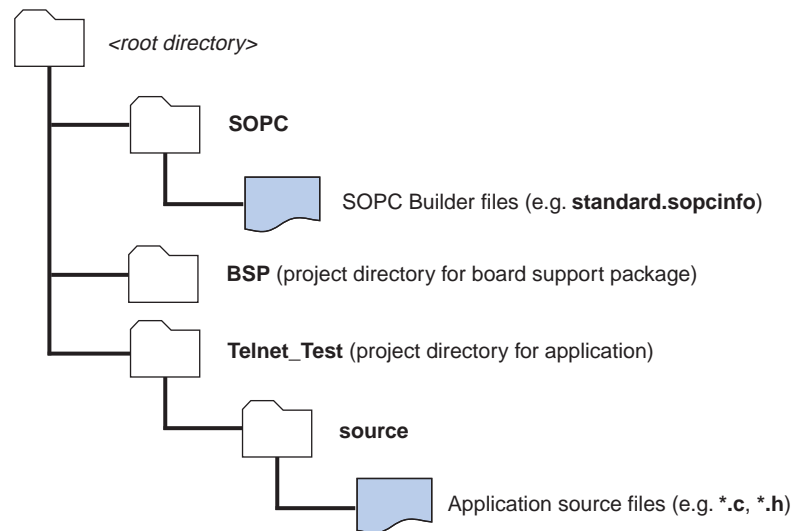
 For more detailed information about debugging projects in the Nios II Software Build Tools for Eclipse, refer to “Importing a Command-Line Project” and “Getting Started” in the *Getting Started with the Graphical User Interface* chapter of the *Nios II Software Developer’s Handbook*.

## Scripting Basics

This section provides an example to teach you how you can create a software application using a command line script.

In this section, assume that you want to build a software application for a Nios II system that features the **lan91c111** component and supports the NicheStack® TCP/IP stack. Furthermore, assume that you have organized the hardware design files and the software source files as shown in [Figure 3-1](#).

**Figure 3-1.** Simple Software Project Directory Structure



## Creating a BSP with a Script

One easy method for creating a BSP is to use the **nios2-bsp** script. The script in [Example 3-1](#) creates a BSP and then builds it.

### **Example 3-1.** nios2-bsp

```
nios2-bsp ucosii . ../SOPC/ --cmd enable_sw_package altera_iniche \
--set altera_iniche.iniche_default_if lan91c111
make
```

[Table 3-2](#) shows the meaning of each argument to the **nios2-bsp** script in [Example 3-1](#).

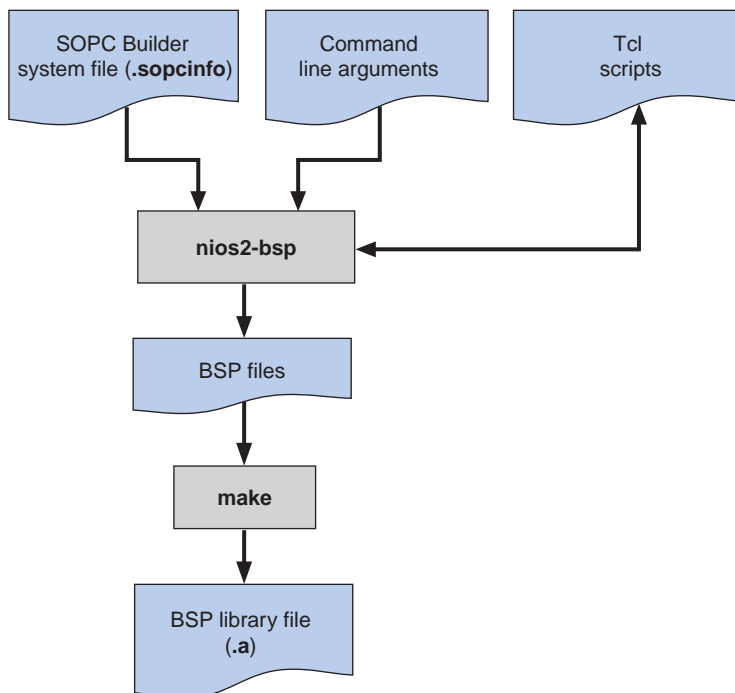


For additional information about the **nios2-bsp** command, refer to “Nios II Software Build Tools Utilities” in the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer’s Handbook*.

**Table 3-2.** nios2-bsp Example Arguments

Argument	Purpose	Further Information
ucosii	Sets the operating system to MicroC/OS-II	“Settings” in the <i>Nios II Software Build Tools Reference</i> chapter of the <i>Nios II Software Developer's Handbook</i>
.	Specifies the directory in which the BSP is to be created	—
../SOPC/	Points to the location of the SOPC Builder system	—
--cmd enable_sw_package altera_iniche	Adds the NicheStack TCP/IP stack software package to the BSP	“Settings” and “Tcl Commands” in the <i>Nios II Software Build Tools Reference</i> chapter of the <i>Nios II Software Developer's Handbook</i>
--set altera_iniche.iniche_default_if lan91c111	Specifies the default hardware interface for the NicheStack TCP/IP Stack - Nios II Edition	“Settings” in the <i>Nios II Software Build Tools Reference</i> chapter of the <i>Nios II Software Developer's Handbook</i>

Figure 3-2 shows the flow to create a BSP using the **nios2-bsp** script. The **nios2-bsp** script uses the **.sopcinfo** file to create the BSP files. You can override default settings chosen by **nios2-bsp** by supplying command-line arguments, Tcl scripts, or both.

**Figure 3-2.** nios2-bsp Command Flow



## Creating an Application Project with a Script

You use **nios2-app-generate-makefile** to create application projects. The script in [Example 3-2](#) creates an application project and builds it.

### Example 3-2. nios2-app-generate-makefile

```
nios2-app-generate-makefile --bsp-dir ../BSP \
    --elf-name telnet-test.elf --src-dir source/
make
```

[Table 3-3](#) shows the meaning of each argument in [Example 3-2](#).

**Table 3-3.** nios2-app-generate-makefile Example Arguments

Argument	Purpose
--bsp-dir ../BSP	Specifies the location of the BSP on which this application is based
--elf-name telnet-test.elf	Specifies the name of the executable file
--src-dir source/	Tells <b>nios2-app-generate-makefile</b> where to find the C source files



For further information about each command argument in [Table 3-3](#), refer to “Nios II Software Build Tools Utilities” in the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer’s Handbook*. For more detail about the software example scripts, refer to “Nios II Example Design Scripts” in the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer’s Handbook*.

## Running make

**nios2-bsp** places all BSP files in the BSP directory, specified on the command line with argument **--bsp-dir**. After running **nios2-bsp**, you run **make**, which compiles the source code. The result of compilation is the BSP library file, also in the BSP directory. The BSP is ready to be linked with your application.

You can specify multiple targets on a **make** command line. For example, the following command removes existing object files in the current project directory, builds the project, downloads the project to a board, and runs it:

```
make clean download-elf
```

You can modify an application or user library makefile with the **nios2-lib-update-makefile** and **nios2-app-update-makefile** utilities. With these utilities, you can execute the following tasks:

- Add source files to a project
- Remove source files from a project
- Add compiler options to a project’s make rules
- Modify or remove compiler options in a project’s make rules

## Using the Nios II C2H Compiler

The Nios II software build tools support the Nios II C2H Compiler with the **nios2-c2h-generate-makefile** command. The C2H Compiler implements hardware acceleration in the Nios II processor.



The **nios2-c2h-generate-makefile** script is available to support pre-existing command-line C2H projects. Create new C2H projects using the Nios II Integrated Development Environment (IDE).

Perform the following steps to create and build a software project with a C2H accelerator:

1. Create a working directory for your hardware and software projects. The following steps refer to this directory as *<projects>*.
2. Locate a Nios II hardware example corresponding to your Nios development board, and copy the hardware example to your *<projects>* working directory.
3. Select an application in a subdirectory of **software\_examples/app** in the *<projects>* directory. The following steps refer to the application directory as *<application>*.
4. Select a BSP appropriate to your application. The following steps refer to the BSP directory as *<BSP>*. Create and build the BSP with the **create-this-bsp** script.
5. Create the application project by typing the following command:

```
nios2-app-generate-makefile --c2h --bsp-dir <BSP> --src-dir <application>↵
```

The **--c2h** command-line option causes **Makefile** to include the C2H makefile fragment, **c2h.mk**.

6. Create the C2H makefile fragment by typing the following command:

```
nios2-c2h-generate-makefile \
--sopc=../c2h_tutorial_hw/NiosII_<board name>_standard_sopc.sopcinfo\
--accelerator=do_dma,dma_c2h_tutorial.c --enable_quartus=1
```

When **nios2-c2h-generate-makefile** completes, you can find the makefile fragment, **c2h.mk**, in the *<application>* directory.

7. Build the application project by typing **make**. To build the project, the makefiles perform the following tasks:
  - a. Start the C2H Compiler to analyze the accelerated function, generate the hardware accelerator, and generate the C wrapper function.
  - b. Run SOPC Builder to incorporate the accelerator in the SOPC Builder system. The build process modifies the **.sopcinfo** file to include the new accelerator as a component in the system.
  - c. Run the Quartus II software to compile the hardware project and regenerate the **.sof** file.
  - d. Rebuild the C/C++ application project and link the accelerator wrapper function to the application.



Close SOPC Builder while building Nios II C/C++ projects with accelerated functions. The C2H Compiler modifies the SOPC Builder system in the background. If SOPC Builder is open while you build a Nios II IDE project with C2H accelerators, the system displayed in the SOPC Builder window can become out-of-date. If you inadvertently leave SOPC Builder open while building an accelerator with the C2H Compiler, be sure to close the **.sopcinfo** file without saving it. If you save the out-of-date file, you overwrite your accelerator-enhanced system file.



For more details about **nios2-c2h-generate-makefile**, refer to the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*. For more details about the C2H acceleration example given here, refer to the *Getting Started Tutorial* chapter of the *Nios II C2H Compiler User Guide*.

### Nios II C2H Makefiles

The **nios2-c2h-generate-makefile** command creates the C2H makefile fragment, **c2h.mk**, which specifies all accelerators and accelerator options for an application.

**nios2-c2h-generate-makefile** creates a new **c2h.mk** each time it is executed, overwriting the existing **c2h.mk**.



You must use the **--c2h** flag when calling **nios2-app-generate-makefile** to build your application with the C2H Compiler. This flag causes your application makefile to include the static C2H **make** rules. These rules in turn include the **c2h.mk** fragment generated by **nios2-c2h-generate-makefile**.

## Referenced Documents

This chapter references the following documents:

- *Getting Started with the Graphical User Interface* chapter of the *Nios II Software Developer's Handbook*
- *Nios II Software Build Tools* chapter of the *Nios II Software Developer's Handbook*
- *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*
- *Nios II Hardware Development Tutorial*
- *Nios II C2H Compiler User Guide*

## Document Revision History

Table 3-4 shows the revision history for this document.

**Table 3-4.** Document Revision History

Date & Document Version	Changes Made	Summary of Changes
November 2009 v9.1.0	<ul style="list-style-type: none"> <li>■ Repurpose and retitle this chapter as an introduction to Nios II Software Build Tools command-line usage</li> <li>■ Information about the BSP Editor moved to the <i>Getting Started with the Graphical User Interface</i> chapter</li> </ul>	Introduced the Nios II Software Build Tools for Eclipse
March 2009 v9.0.0	<ul style="list-style-type: none"> <li>■ Describe BSP Editor</li> <li>■ Reorganize and update information and terminology to clarify role of Nios II Software Build Tools</li> <li>■ Correct minor typographical errors</li> </ul>	BSP Editor
May 2008 v8.0.0	No change from previous release	—
October 2007 v7.2.0	Repurpose this chapter as a “getting started” guide. Move descriptive and reference material to separate chapters.	Additional “getting started” material. Descriptive and reference material in separate chapters.
May 2007 v7.1.0	Initial Release	—

This chapter describes the Nios® II Software Build Tools, a set of utilities and scripts that create and build C/C++ application projects, user library projects, and board support packages (BSPs). The Nios II Software Build Tools support a repeatable, scriptable, and archivable process for creating your software product.

You can invoke the Nios II Software Build Tools through either of the following user interfaces:

- The Eclipse™ graphical user interface (GUI)
- The Nios II Command Shell

The purpose of this chapter is to make you familiar with the internal functionality of the Nios II Software Build Tools, independent of the user interface employed.



Before reading this chapter, consider getting an introduction to the Nios II Software Build Tools by first reading one of the following chapters:

- *Getting Started with the Graphical User Interface* chapter of the *Nios II Software Developer's Handbook*
- *Getting Started from the Command Line* chapter of the *Nios II Software Developer's Handbook*

This chapter contains the following sections:

- "Road Map for the Software Build Tools"
- "Makefiles" on page 4-3
- "Nios II Software Projects" on page 4-4
- "Common BSP Tasks" on page 4-8
- "Details of BSP Creation" on page 4-20
- "Tcl Scripts for BSP Settings" on page 4-26
- "Revising Your BSP" on page 4-29
- "Specifying BSP Defaults" on page 4-34
- "Device Drivers and Software Packages" on page 4-38
- "Boot Configurations" on page 4-38
- "Altera-Provided Development Tools" on page 4-41
- "Restrictions" on page 4-46

This chapter assumes you are familiar with the following topics:

- The GNU **make** utility. Altera recommends you use version 3.80 or later. On the Windows platform, GNU **make** version 3.80 is provided with the Nios II EDS.



You can obtain general information about GNU **make** from the Free Software Foundation, Inc. ([www.gnu.org](http://www.gnu.org)).

- Board support packages.

Depending on how you use the tools, you might also need to be familiar with the following topics:

- Micrium MicroC/OS-II. For information, refer to *MicroC/OS-II - The Real Time Kernel* by Jean J. Labrosse (CMP Books).
- Tcl scripting language.

## Road Map for the Software Build Tools

Before you start using the Nios II Software Build Tools, it is important to understand their scope. This section helps you understand their purpose, what they include, and what each tool does. Understanding these points helps you determine how each tool fits in with your development process, what parts of the tools you need, and what features you can disregard for now.

### What the Build Tools Create

The purpose of the build tools is to create and build Nios II software projects. A Nios II project is a makefile with associated source files.

The Software Build Tools create the following types of projects:

- Nios II application—A program implementing some desired functionality, such as control or signal processing.
- Nios II BSP—A library providing access to hardware in the Nios II system, such as UARTs and other I/O devices. A BSP provides a software runtime environment customized for one processor in an SOPC Builder system. A BSP optionally also includes the operating system, and other basic system software packages such as communications protocol stacks.
- User library—A library implementing a collection of reusable functions, such as graphics algorithms.

### Comparing the Command Line with Eclipse

Aside from the Eclipse GUI, there are very few differences between the Software Build Tools command line and the Nios II Software Build Tools for Eclipse. [Table 4-1](#) lists the differences.

**Table 4-1.** Differences between Nios II Software Build Tools for Eclipse and the Command Line

Feature	Eclipse	Command Line
Project source file management	Specify sources automatically, e.g. by dragging and dropping into project	Specify sources manually using command arguments
Debugging	Yes	Import project to Eclipse environment
Integrates with custom shell scripts and tool flows	No	Yes

The Nios II Software Build Tools for Eclipse provide access to a large, useful subset of Software Build Tools functionality. Any project you create in Eclipse can also be created using the Software Build Tools from the command line or in a script. Create your software project using the interface that is most convenient for you. Later, it is easy to perform additional project tasks in the other interface if you find it advantageous to do so.

## Makefiles

Makefiles are a key element of Nios II C/C++ projects. The Nios II Software Build Tools include powerful tools to create makefiles. An understanding of how these tools work can help you make the most optimal use of them.

The Nios II Software Build Tools create two kinds of makefiles:

- Application or user library makefile—A simple makefile that builds the application or user library with user-provided source files
- BSP makefile—A more complex makefile, generated to conform to user-specified settings and the requirements of the target SOPC Builder system

It is not necessary to use the generated application and user library makefiles if you prefer to write your own. However, Altera recommends that you use the Software Build Tools to manage and modify BSP makefiles.

Generated makefiles are platform-independent, calling only utilities provided with the Nios II EDS (such as **nios2-elf-gcc**).

The generated makefiles have a straightforward structure, and each makefile has in-depth comments explaining how it works. Altera recommends that you study these makefiles for further information about how they work. Generated BSP makefiles consist of a single main file and a small number of makefile fragments, all of which reside in the BSP directory. Each application and user library has one makefile, located in the application or user library directory.

## Modifying Makefiles

It is not necessary to edit makefiles by hand. The Nios II Software Build Tools for Eclipse™ offer GUI tools for makefile management.



For further information, refer to the *Getting Started with the Graphical User Interface* chapter of the *Nios II Software Developer's Handbook*.

On the command line, use one of the following utilities to update your makefile:

- **nios2-bsp-update-makefile**
- **nios2-app-update-makefile**
- **nios2-lib-update-makefile**



After making changes to a makefile, run **make clean** before rebuilding your project. If you are using the Nios II Software Build Tools for Eclipse, this happens automatically.

## Makefile Targets

Table 4-2 shows the application makefile targets. Altera recommends that you study the generated makefiles for further details about these targets.

**Table 4-2.** Application Makefile Targets

Target	Operation
help	Displays all available application makefile targets.
all (default)	Builds the associated BSP and libraries, and then builds the application executable file.
app	Builds only the application executable file.
bsp	Builds only the BSP.
libs	Builds only the libraries and the BSP.
clean	Performs a clean build of the application. Deletes all application-related generated files. Leaves associated BSP and libraries alone.
clean_all	Performs a clean build of the application, and associated BSP and libraries (if any).
clean_bsp	Performs a clean build of the BSP.
clean_libs	Performs a clean build of the libraries and the BSP.
download-elf	Builds the application executable file and then downloads and runs it.
program-flash	Runs the Nios II flash programmer to program your flash memory.

**Note to Table 4-2:**

- (1) You can use the `download-elf` makefile target if the host system is connected to a single USB-Blaster™ download cable. If you have more than one download cable, you must download your executable with a separate command. Set up a run configuration in the Nios II Software Build Tools for Eclipse, or use **nios2-download**, with the `--cable` option to specify the download cable.

## Nios II Software Projects

The Nios II Software Build Tools support the following kinds of software projects:

- C/C++ application projects
- C/C++ user library projects
- BSP projects

This section discusses each type of project in detail.



## Applications and Libraries

The Nios II Software Build Tools have nearly identical support for C/C++ applications and libraries. The support for applications and libraries is very simple. For each case, the Software Build tools generate a private makefile (named **Makefile**). The private makefile is used to build the application or user library.

The private makefile builds one of two types of files:

- A **.elf** file—For an application
- A library archive file (**.a**)—For a user library

For a user library, the Software Build Tools also generate a public makefile, called **public.mk**. The public makefile is included in the private makefile for any application (or other user library) that uses the user library.

When you create a makefile for an application or user library, you provide the Software Build tools with a list of source files and a reference to a BSP directory. The BSP directory is mandatory for applications and optional for libraries.

The Nios II Software Build Tools examine the extension of each source file to determine the programming language. Table 4–3 shows the supported programming languages with the corresponding file extensions.

**Table 4–3.** Supported Source File Types

Programming Language	File Extensions (1)
C	.c
C++	.cpp, .cxx, .cc
Nios II assembly language; sources are built directly by the Nios II assembler without preprocessing	.s
Nios II assembly language; sources are preprocessed by the Nios II C preprocessor, allowing you to include header files	.S

**Note to Table 4–3:**

(1) All file extensions are case-sensitive.

## Board Support Packages

A Nios II BSP project is a specialized library containing system-specific support code. A BSP provides a software runtime environment customized for one processor in an SOPC Builder system. The BSP isolates your application from system-specific details such as the memory map, available devices, and processor configuration.

A BSP includes a **.a** file, header files (for example, **system.h**), and a linker script (**linker.x**). You use these BSP files when creating an application.

The Nios II Software Build Tools support two types of BSPs: Altera® Hardware Abstraction Layer (HAL) and Micrium MicroC/OS-II. MicroC/OS-II is a layer on top of the Altera HAL and shares a common structure.

## Overview of BSP Creation

The Nios II Software Build Tools create your BSP for you. The tools provide a great deal of power and flexibility, enabling you to control details of your BSP implementation while maintaining compatibility with an SOPC Builder system which might change.

By default, the tools generate a basic BSP for a Nios II system. If you require more detailed control over the characteristics of your BSP, the Nios II Software Build Tools provide that control, as described in the remaining sections of this chapter.

## Parts of a Nios II BSP

### Hardware Abstraction Layer

The HAL provides a single-threaded UNIX-like C/C++ runtime environment. The HAL provides generic I/O devices, allowing you to write programs that access hardware using the newlib C standard library routines, such as `printf()`. The HAL interfaces to HAL device drivers, which access peripheral registers directly, abstracting hardware details from the software application. This abstraction minimizes or eliminates the need to access hardware registers directly to connect to and control peripherals.



For complete details about the HAL, refer to the *Hardware Abstraction Layer* section and the *HAL API Reference* chapter of the *Nios II Software Developer's Handbook*.

### Newlib C Standard Library

Newlib is an open source implementation of the C standard library intended for use on embedded systems. It is a collection of common routines such as `printf()`, `malloc()`, and `open()`.

### Device Drivers

Each device driver manages a hardware component. By default, the HAL instantiates a device driver for each component in your SOPC Builder system that needs a device driver. In the Nios II software development environment, a device driver has the following properties:

- A device driver is associated with a specific SOPC Builder component.
- A device driver might have settings that impact its compilation. These settings become part of the BSP settings.

### Optional Software Packages

A software package is source code that you can optionally add to a BSP project to provide additional functionality. The NicheStack® TCP/IP - Nios II Edition is an example of a software package.

In the Nios II software development environment, a software package typically has the following properties:

- A software package is not associated with specific hardware.
- A software package might have settings that impact its compilation. These settings become part of the BSP settings.



In the Nios II software development environment, a software package is distinct from a library project. A software package is part of the BSP project, not a separate library project.

### Optional Real-Time Operating System

The Nios II EDS includes an implementation of the third-party MicroC/OS-II RTOS that you can optionally include in your BSP. MicroC/OS-II is built on the HAL, and implements a simple, well-documented RTOS scheduler. You can modify settings that become part of the BSP settings. Other operating systems are available from third-party vendors.

The Micrium MicroC/OS-II is a multi-threaded run-time environment. It is built on the Altera HAL.

The MicroC/OS-II directory structure is a superset of the HAL BSP directory structure. All HAL BSP generated files also exist in the MicroC/OS-II BSP.

The MicroC/OS-II source code resides in the **UCOSII** directory. The **UCOSII** directory is contained in the BSP directory, like the **HAL** directory, and has the same structure (that is, **src** and **inc** directories). The **UCOSII** directory contains only copied files.

The MicroC/OS-II BSP library archive is named **libucosii\_bsp.a**. You use this file the same way you use **libhal\_bsp.a** in a HAL BSP.

## Software Build Process

To create a software project with the Nios II Software Build Tools, you perform several high-level steps:

1. Obtain the hardware design on which the software is to run. When you are learning about the build tools, this might be a Nios II example design. When you are developing your own design, it is probably a design developed by someone in your organization. Either way, you need to have the SOPC Information File (**.sopcinfo**).
2. Decide what features the BSP requires. For example, does it need to support an RTOS? Does it need other specialized software support, such as a TCP/IP stack? Does it need to fit in a small memory footprint? The answers to these questions tell you what BSP features and settings to use.



For more information about available BSP settings, refer to the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*.

3. Define a BSP. Use some of the Nios II Software Build Tools to specify the components in the BSP, and the values of any relevant settings. The result of this step is a BSP settings file, called **settings.bsp**. For more information about creating BSPs, refer to “**Board Support Packages**” on page 4-5.
4. Create a BSP makefile using the Nios II build tools.

5. Optionally create a user library. If you need to include a custom software user library, you collect the user library source files in a single directory, and create a user library makefile. The Nios II build tools can create a makefile for you. You can also create a makefile by hand, or you can autogenerate a makefile and then customize it by hand. For more information about creating user library projects, refer to [“Applications and Libraries” on page 4-5](#).
6. Collect your application source code. When you are learning, this might be a Nios II software example. When you are developing a product, it is probably a collection of C/C++ source files developed by someone in your organization. For more information about creating application projects, refer to [“Applications and Libraries” on page 4-5](#).
7. Create an application makefile. The easiest approach is to let the Nios II build tools create the makefile for you. You can also create a makefile by hand, or you can autogenerate a makefile and then customize it by hand. For more information about creating makefiles, refer to [“Makefiles” on page 4-3](#).

## Common BSP Tasks

The Nios II Software Build Tools create a BSP for you with useful default settings. However, for many tasks you must manipulate the BSP explicitly. This section describes the following common BSP tasks, and how you carry them out.

- [“Using Version Control” on page 4-9](#)
- [“Copying, Moving, or Renaming a BSP” on page 4-10](#)
- [“Handing Off a BSP” on page 4-10](#)
- [“Creating Memory Initialization Files” on page 4-10](#)
- [“Modifying Linker Memory Regions” on page 4-11](#)
- [“Creating a Custom Linker Section” on page 4-12](#)
- [“Changing the Default Linker Memory Region” on page 4-16](#)
- [“Changing a Linker Section Mapping” on page 4-16](#)
- [“Creating a BSP for a Nios Development Board” on page 4-17](#)
- [“Querying Settings” on page 4-18](#)
- [“Managing Device Drivers” on page 4-18](#)
- [“Creating a Custom Version of Newlib” on page 4-18](#)
- [“Controlling the stdio Device” on page 4-19](#)
- [“Configuring Optimization and Debugger Options” on page 4-19](#)

Although this section describes tasks in terms of the Software Build Tools command line flow, you can also carry out most of these tasks with the Nios II Software Build Tools for Eclipse, described in the [Getting Started with the Graphical User Interface](#) chapter of the *Nios II Software Developer’s Handbook*.

## Adding the Nios II Software Build Tools to Your Tool Flow

A common reason for using the Software Build Tools is to enable you to integrate your software build process with other tools that you use for system development, including non-Altera tools. This section describes several scenarios in which you can incorporate the build tools in an existing tool chain.

### Using Version Control

One common tool flow requirement is version control. By placing an entire software project, including both source and makefiles, under version control, you can ensure reproducible results from software builds.

When you are using version control, it is important to know which files to add to your version control database. With the Nios II Software Build Tools, the version control requirements depend on what you are trying to do and how you create the BSP.

If you create a BSP by running your own script that calls **nios2-bsp**, you can put your script under version control. If your script provides any Tcl scripts to **nios2-bsp** (using the `--script` option), you must also put these Tcl scripts under version control. If you install a new release of Nios II EDS and run your script to create a new BSP or to update an existing BSP, the internal implementation of your BSP might change slightly due to improvements in Nios II EDS.



Refer to “[Revising Your BSP](#)” on page 4-29 for a discussion of BSP regeneration with Nios II EDS updates.

If you create a BSP by running **nios2-bsp** manually on the command line or by running your own script that calls **nios2-bsp-generate-files**, you can put your BSP settings file (typically named **settings.bsp**) under version control. As in the scripted **nios2-bsp** case, if you install a new release of Nios II EDS and recreate your BSP, the internal implementation might change slightly.

If you want the exact same BSP after installing a new release of Nios II EDS, create your BSP and then put the entire BSP directory under version control before running `make`. If you have already run `make`, run `make clean` to remove all built files before adding the directory contents to your version control database. The Software Build Tools place all the files required to build a BSP in the BSP directory. If you install a new release of Nios II EDS and run `make` on your BSP, the implementation is the same, but the binary output might not be identical.

If you create a script that uses the command-line tools **nios2-bsp-create-settings** and **nios2-bsp-generate-files** explicitly, or you use these tools directly on the command line, it is possible to create the BSP settings file in a directory different from the directory where the generated BSP files reside. However, in most cases, when you want to store a BSP's generated files directory under source control, you also want to store the BSP settings file. Therefore, it is best to keep the settings file with the other BSP files. You can rebuild the project without the BSP settings file, but the settings file allows you to update and query the BSP.



Because the BSP depends on a **.sopcinfo** file, you must usually store the **.sopcinfo** file in source control along with the BSP. The BSP settings file stores the **.sopcinfo** file path as a relative or absolute path, according to the definition on the **nios2-bsp** or **nios2-bsp-create-settings** command line. You must take the path into account when retrieving the BSP and the **.sopcinfo** file from source control.

### Copying, Moving, or Renaming a BSP

BSP makefiles have only relative path references to project source files. Therefore you are free to copy, move, or rename the entire BSP. If you specify a relative path to the SOPC system file when you create the BSP, you must ensure that the **.sopcinfo** file is still accessible from the new location of the BSP. This **.sopcinfo** file path is stored in the BSP settings file.

Run `make clean` when you copy, move, or rename a BSP. The make dependency files (**.d**) have absolute path references. `make clean` removes the **.d** files, as well as linker object files (**.o**) and **.a** files. You must rebuild the BSP before linking an application with it. You can use the `make clean_bsp` command to combine these two operations.



For information about **.d** files, refer to the GNU make documentation, available from the Free Software Foundation, Inc. ([www.gnu.org](http://www.gnu.org)).

Another way to copy a BSP is to run the **nios2-bsp-generate-files** command to populate a BSP directory and pass it the path to the BSP settings file of the BSP that you wish to copy.

If you rename or move a BSP, you must manually revise any references to the BSP name or location in application or user library makefiles.

### Handing Off a BSP

In some engineering organizations, one group (such as systems engineering) creates a BSP and hands it off to another group (such as applications software) to use while developing an application. In this situation, Altera recommends that you as the BSP developer generate the files for a BSP without building it (that is, do not run `make`) and then bundle the entire BSP directory, including the settings file, with a utility such as **tar** or **zip**. The software engineer who receives the BSP can simply run `make` to build the BSP.

## Linking and Locating

When autogenerating a HAL BSP, the Software Build Tools make some reasonable assumptions about how you want to use memory, as described in “[Specifying the Default Memory Map](#)” on page 4-37. However, in some cases these assumptions might not work for you. For example, you might implement a custom boot configuration that requires a bootloader in a specific location; or you might want to specify which memory device contains your interrupt service routines (ISRs).

This section describes several common scenarios in which the Software Build Tools allow you to control details of memory usage.

### Creating Memory Initialization Files

The **mem\_init.mk** file includes targets designed to help you create memory initialization files (**.dat**, **.hex**, **.sym**, and **.flash**). The **mem\_init.mk** file is designed to be included in your application makefile. Memory initialization files are used for HDL simulation, for Quartus® II compilation of initializable FPGA on-chip memories, and for flash programming. Initializable memories include M512 and M4K, but not MRAM.

Table 4-4 shows the **mem\_init.mk** targets. Although the application makefile provides all these targets, it does not build any of them by default. The Software Build Tools create the memory initialization files in the application directory (under a directory named **mem\_init**). They optionally copy them to your Quartus II project directory and HDL simulation directory, as described in Table 4-4.



The Nios II Software Build Tools do not generate a definition of `QUARTUS_PROJECT_DIR` in your application makefile. If you have an on-chip RAM, and require that a compiled software image be inserted in your SRAM Object File (.sof) at Quartus II compilation, you must manually specify the value of `QUARTUS_PROJECT_DIR` in your application makefile. You must define `QUARTUS_PROJECT_DIR` before the **mem\_init.mk** file is included in the application makefile, as in the following example:

```
QUARTUS_PROJECT_DIR = ../my_hw_design
MEM_INIT_FILE := $(BSP_ROOT_DIR)/mem_init.mk
include $(MEM_INIT_FILE)
```

**Table 4-4.** mem\_init.mk Targets

Target	Operation
mem_init_install	Generates memory initialization files in the application <b>mem_init</b> directory. If the <code>QUARTUS_PROJECT_DIR</code> variable is defined, <b>mem_init.mk</b> copies memory initialization files to your Quartus II project directory named <code>\$(QUARTUS_PROJECT_DIR)</code> . If the <code>SOPC_NAME</code> variable is defined, <b>mem_init.mk</b> copies memory initialization files to your HDL simulation directory named <code>\$(QUARTUS_PROJECT_DIR)/\$(SOPC_NAME)_sim</code> .
mem_init_generate	Generates all memory initialization files in the application <b>mem_init</b> directory.
mem_init_clean	Removes the memory initialization files from the application <b>mem_init</b> directory.
hex	Generates all hex files.
dat	Generates all dat files.
sym	Generates all sym files.
flash	Generates all flash files.
<memory name>	Generates all memory initialization files for <memory name> component.

## Modifying Linker Memory Regions

If the linker memory regions that are created by default do not meet your needs, BSP Tcl commands let you modify the memory regions as desired.

Suppose you have a memory region named `onchip_ram`. Example 4-1 shows a Tcl script named **reserve\_1024\_onchip\_ram.tcl** that separates the top 1024 bytes of `onchip_ram` to create a new region named `onchip_special`.



For an explanation of each Tcl command used in this example, refer to the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*.



**Example 4-1. Reserved Memory Region**


---

```
# Get region information for onchip_ram memory region.
# Returned as a list.
set region_info [get_memory_region onchip_ram]
# Extract fields from region information list.
set region_name [lindex $region_info 0]
set slave_desc [lindex $region_info 1]
set offset [lindex $region_info 2]
set span [lindex $region_info 3]
# Remove the existing memory region.
delete_memory_region $region_name
# Compute memory ranges for replacement regions.
set split_span 1024
set new_span [expr $span-$split_span]
set split_offset [expr $offset+$new_span]
# Create two memory regions out of the original region.
add_memory_region onchip_ram $slave_desc $offset $new_span
add_memory_region onchip_special $slave_desc $split_offset $split_span
```

---

If you pass this Tcl script to **nios2-bsp**, it runs after the default Tcl script runs and sets up a linker region named `onchip_ram0`. You pass the Tcl script to **nios2-bsp** as follows:

```
nios2-bsp hal my_bsp --script reserve_1024_onchip_ram.tcl
```



Take care that one of the new memory regions has the same name as the original memory region.

If you run **nios2-bsp** again to update your BSP without providing the `--script` option, your BSP reverts to the default linker memory regions and your `onchip_special` memory region disappears. To preserve it, you can either provide the `--script` option to your Tcl script or pass the `DONT_CHANGE` keyword to the default Tcl script as follows:

```
nios2-bsp hal my_bsp --default_memory_regions DONT_CHANGE
```

Altera recommends that you use the `--script` approach when updating your BSP. This approach allows the default Tcl script to update memory regions if memories are added, removed, renamed, or resized. Using the `DONT_CHANGE` keyword approach does not handle any of these cases because the default Tcl script does not update the memory regions at all.

For details about using the `--script` argument, refer to [“Calling a Custom BSP Tcl Script” on page 4-26](#).

**Creating a Custom Linker Section**

The Nios II Software Build Tools provide a Tcl command to create a linker section. [Table 4-5](#) lists the default section names.

The default Tcl script creates these default sections for you using the `add_section_mapping` Tcl command.



**Table 4-5.** Nios II Default Section Names

.entry
.exceptions
.text
.rodata
.rwdata
.bss
.heap
.stack

To create your own section named `special_section` that is mapped to the linker region named `onchip_special`, use the following Tcl command to run **nios2-bsp**:

```
nios2-bsp hal my_bsp --cmd add_section_mapping special_section onchip_special
```

When the **nios2-bsp-generate-files** utility (called by **nios2-bsp**) generates the linker script **linker.x**, the linker script has a new section mapping. The order of section mappings in the linker script is determined by the order in which the `add_section_mapping` command creates the sections. If you use **nios2-bsp**, the default Tcl script runs before the `--cmd` option that creates the `special_section` section.

If you run **nios2-bsp** again to update your BSP, you do not need to provide the `add_section_mapping` command again because the default Tcl script only modifies section mappings for the default sections listed in [Table 4-5](#).

### Dividing a Linker Region to Create a New Region and Section

[Example 4-2](#) creates a section named `.isrs` in the `tightly_coupled_instruction_memory` on-chip memory.

#### **Example 4-2.** Create `hal_isrs_section.tcl` script

```
# Get region information for tightly_coupled_instruction_memory memory
region.
# Returned as a list.
set region_info [get_memory_region tightly_coupled_instruction_memory]
# Extract fields from region information list.
set region_name [lindex $region_info 0]
set slave [lindex $region_info 1]
set offset [lindex $region_info 2]
set span [lindex $region_info 3]
# Remove the existing memory region.
delete_memory_region $region_name
# Compute memory ranges for replacement regions.
set split_span 1024
set new_span [expr $span-$split_span]
set split_offset [expr $offset+$new_span]
# Create two memory regions out of the original region.
add_memory_region tightly_coupled_instruction_memory $slave $offset
$new_span
add_memory_region isrs_region $slave $split_offset $split_span
add_section_mapping .isrs isrs_region
```

The following steps describe the use of this script:

1. Create a working directory for your hardware and software projects. The following steps refer to this directory as *<projects>*.
2. Make *<projects>* the current working directory.
3. Find the full-featured Nios II hardware example corresponding to your Nios development board. For example, if you have a Cyclone® II development board, select *<Nios II EDS install path>/examples/verilog/niosII\_cycloneII\_2c35/full\_featured*.

This example uses the Verilog HDL full-featured hardware example design. You can select the language you prefer (Verilog HDL or VHDL)

4. Copy the hardware example to your working directory, using a command such as the following:

```
cp -R $SOPC_KIT_NIOS2/examples/verilog/niosII_cycloneII_2c35/full_featured .
```

5. Ensure that the working directory and all subdirectories are writable by typing the following command:

```
chmod -R +w .
```

6. The *<projects>* directory contains a subdirectory named **software\_examples/bsp**. Make this directory the current working directory by typing the following command:

```
cd full_featured/software_examples/bsp
```

7. In the **bsp** directory, a subdirectory named **hal\_default** contains the **create-this-bsp** script for a default HAL-based BSP. Copy this directory, name the copy **hal\_isrs\_section**, and change directories to the new directory, by typing the following commands:

```
cp -R hal_default hal_isrs_section
cd hal_isrs_section
```

8. Create **isrs\_section\_script.tcl**, shown in [Example 4-2](#). This script splits off 1 KByte of RAM from the region named **tightly\_coupled\_instruction\_memory**, gives it the name **isrs\_region**, and then calls **add\_section\_mapping** to add the **.isrs** section to **isrs\_region**.
9. The *<projects>* directory contains a subdirectory named **software\_examples/app/tcm**. Make this directory the current working directory by typing the following command:

```
cd ../../app/tcm
```

10. Edit the **create-this-app** script. Change occurrences of **hal\_default** to **hal\_isrs\_section**.
11. Create and build the application with the **create-this-app** script as follows:
12. Edit **timer\_interrupt\_latency.h**. In the **timer\_interrupt\_latency\_irq()** function, change the **.section** directive from **.exceptions** to **.isrs**.
13. Rebuild the application by running **make**, as follows:

```
make
```

14. After make completes successfully, examine the object dump file, **tcm.objdump**, shown in [Example 4-3](#). **tcm.objdump** shows that the new **.isrs** section is located in the tightly coupled instruction memory.
15. Examine the linker script file, **linker.x**, shown in [Example 4-4](#). **linker.x** places the new region **isrs\_region** in tightly-coupled instruction memory, adjacent to the **tightly\_coupled\_instruction\_memory** region.

You can run the example by carrying out the following steps:

1. Open another shell and run **nios2-terminal**.
2. If your hardware is not already configured with the correct **.sof** file, type the following command:

```
nios2-configure-sof ../../../*.sof
```

3. In your original shell, type the following command:

```
nios2-download -g tcm.elf
```

**Example 4-3.** Excerpts from tcm.objdump

---

```
Sections:
Idx Name              Size      VMA      LMA      File off  Algn
  .
  .
  .
  6 .isrs              000000c0  04000c00  04000c00  000000b4  2**2
                        CONTENTS, ALLOC, LOAD, READONLY, CODE
  .
  .
  .
  9 .tightly_coupled_instruction_memory 00000000  04000000  04000000
00013778  2**0
                        CONTENTS
  .
  .
  .

SYMBOL TABLE:
00000000 l d .entry 00000000
30000020 l d .exceptions 00000000
30000150 l d .text 00000000
30010e14 l d .rodata 00000000
30011788 l d .rwdata 00000000
30013624 l d .bss 00000000
04000c00 l d .isrs 00000000
00000020 l d .ext_flash 00000000
03200000 l d .epcs_controller 00000000
04000000 l d .tightly_coupled_instruction_memory 00000000
04004000 l d .tightly_coupled_data_memory 00000000
  .
  .
  .
```

---

**Example 4-4.** Excerpt From linker.x

---

```

MEMORY
{
    reset : ORIGIN = 0x0, LENGTH = 32
    tightly_coupled_instruction_memory : ORIGIN = 0x4000000, LENGTH = 3072
    isrs_region : ORIGIN = 0x4000c00, LENGTH = 1024

    .
    .
    .
}

```

---

**Changing the Default Linker Memory Region**

The default Tcl script chooses the largest memory region connected to your Nios II processor as the default region. All default memory sections specified in [Table 4-5 on page 4-13](#) are mapped to this default region. You can pass in a command-line option to the default Tcl script to override this default mapping. To map all default sections to onchip\_ram, type the following command:

```
nios2-bsp hal my_bsp --default_sections_mapping onchip_ram↵
```

If you run **nios2-bsp** again to update your BSP, the default Tcl script overrides your default sections mapping. To prevent your default sections mapping from being changed, provide **nios2-bsp** with the original `--default_sections_mapping` command-line option or pass it the `DONT_CHANGE` value for the memory name instead of onchip\_ram.

**Changing a Linker Section Mapping**

If some of the default section mappings created by the default Tcl script do not meet your needs, you can use a Tcl command to override the section mappings selectively. To map the `.stack` and `.heap` sections into a memory region named `ram0`, use the following command:

```
nios2-bsp hal my_bsp --cmd add_section_mapping .stack ram0 \
--cmd add_section_mapping .heap ram0↵
```

The other section mappings (for example, `.text`) are still mapped to the default linker memory region.

If you run **nios2-bsp** again to update your BSP, the default Tcl script overrides your section mappings for `.stack` and `.heap` because they are default sections. To prevent your section mappings from being changed, provide **nios2-bsp** with the original `add_section_mapping` command-line options or pass the `--default_sections_mapping DONT_CHANGE` command line to **nios2-bsp**.

Altera recommends using the `--cmd add_section_mapping` approach when updating your BSP because it allows the default Tcl script to update the default sections mapping if memories are added, removed, renamed, or resized.


**Other BSP Tasks**

This section covers some other common situations in which the Software Build Tools are useful.

## Creating a BSP for a Nios Development Board

In some situations, you need to create a BSP separate from any application. Creating a BSP is similar to creating an application. To create a BSP, perform the following steps:

1. Start the Nios II Command Shell.

 For details about the Nios II Command Shell, refer to the *Getting Started from the Command Line* chapter of the *Nios II Software Developer's Handbook*.

2. Create a working directory for your hardware and software projects. The following steps refer to this directory as *<projects>*.
3. Make *<projects>* the current working directory.
4. Find a Nios II hardware example corresponding to your Nios development board. For example, if you have a 2C35 development board, you might select *<Nios II EDS install path>/examples/verilog/niosII\_cycloneII\_2c35/standard*.

This example uses the Verilog HDL standard hardware example design. You can select the language you prefer (Verilog HDL or VHDL), and any type of example design except `small`.

5. Copy the hardware example to your working directory, using a command such as the following:

```
cp -R $SOPC_KIT_NIOS2/examples/verilog\  
/niosII_cycloneII_2c35/standard .
```

6. Ensure that the working directory and all subdirectories are writable by typing the following command:

```
chmod -R +w .
```


The *<projects>* directory contains a subdirectory named **software\_examples/bsp**. The **bsp** directory contains several BSP example directories, such as **hal\_default**. Select the directory containing an appropriate BSP, and make it the current working directory.

 For a description of the example BSPs, refer to “Nios II Example Design Scripts” in the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*.

7. Create and build the BSP with the **create-this-bsp** script by typing the following command:

```
./create-this-bsp
```

Now you have a BSP, with which you can create and build an application.

 Altera recommends that you examine the contents of the **create-this-bsp** script. It is a helpful example if you are creating your own script to build a BSP. **create-this-bsp** calls **nios2-bsp** with a few command-line options to create a customized BSP, and then calls **make** to build the BSP.

## Querying Settings

If you need to write a script that gets some information from the BSP settings file, use the **nios2-bsp-query-settings** utility. To maintain compatibility with future releases of the Nios II EDS, avoid developing your own code to parse the BSP settings file.

If you want to know the value of one or more settings, run **nios2-bsp-query-settings** with the appropriate command-line options. This command sends the values of the settings you requested to `stdout`. Just capture the output of `stdout` in some variable in your script when you call **nios2-bsp-query-settings**. By default, the output of **nios2-bsp-query-settings** is an ordered list of all option values. Use the `-show-names` option to display the name of the setting with its value.



For details about the **nios2-bsp-query-settings** command-line options, refer to the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*.

## Managing Device Drivers

The Nios II Software Build Tools create an **alt\_sys\_init.c** file. By default, the build tools assume that if a device is connected to the Nios II processor, and a driver is available, the BSP must include the most recent version of the driver. However, you might want to use a different version of the driver, or you might not want a driver at all (for example, if your application accesses the device directly).

The Software Build Tools include BSP Tcl commands to manage device drivers. With these commands you can control which driver is used for each device. When the **alt\_sys\_init.c** file is generated, it is set up to initialize drivers as you have requested.

If you are using **nios2-bsp**, you disable the driver for the `uart0` device as follows:

```
nios2-bsp hal my_bsp --cmd set_driver none uart0
```

Use the `--cmd` option to call a Tcl command on the command line. The **nios2-bsp-create-settings** command also supports the `--cmd` option. Alternatively, you can put the `set_driver` command in a Tcl script and pass the script to **nios2-bsp** or **nios2-bsp-create-settings** with the `--script` option.

You replace the default driver for `uart0` with a specific version of a driver as follows:

```
nios2-bsp hal my_bsp --cmd set_driver altera_avalon_uart:6.1 uart0
```

## Creating a Custom Version of Newlib

The Nios II EDS comes with a number of precompiled libraries. These libraries include the newlib libraries (**libc.a** and **libm.a**). The Nios II Software Build Tools allow you to create your own custom compiled version of the newlib libraries.

To create a custom compiled version of newlib, set a BSP setting to the desired compiler flags. If you are using **nios2-bsp**, type the following command:

```
nios2-bsp hal my_bsp --set hal.custom_newlib_flags "-O0 -pg"
```

Because newlib uses the open source **configure** utility, its build flow differs from other files in the BSP. When **Makefile** builds the BSP, it runs the **configure** utility. The **configure** utility creates a makefile in the build directory, which compiles the newlib source. The newlib library files are copied to the BSP directory named `newlib`. The newlib source files are not copied to the BSP.



The Nios II Software Build Tools recompile newlib whenever you introduce new compiler flags. For example, if you use compiler flags to add floating point math hardware support, newlib is recompiled to use the hardware. Recompiling newlib might take several minutes.

## Controlling the stdio Device

The build tools offer several ways to control the details of your stdio device configuration, such as the following:

- To prevent a default stdio device from being chosen, use the following command:  

```
nios2-bsp hal my_bsp --default_stdio none
```
- To override the default stdio device and replace it with uart1, use the following command:  

```
nios2-bsp hal my_bsp --default_stdio uart1
```
- To override the stderr device and replace it with uart2, while allowing the default Tcl script to choose the default stdout and stdin devices, use the following command:

```
nios2-bsp hal my_bsp --set hal.stderr uart2
```

In all these cases, if you run **nios2-bsp** again to update your BSP, you must provide the original command-line options again to prevent the default Tcl script from choosing its own default stdio devices. Alternatively, you can call `--default_stdio` with the `DONT_CHANGE` keyword to prevent the default Tcl script from changing the stdio device settings.

## Configuring Optimization and Debugger Options

By default, the Nios II Software Build Tools create your project with the correct compiler options for debugging environments. These compiler options turn off code optimization, and generate a symbol table for the debugger.

You can control the optimization and debug level through the project makefile, which determines the compiler options. [Example 4-5](#) illustrates how a typical application makefile specifies the compiler options.

### Example 4-5. Default Application Makefile Settings

```
APP_CFLAGS_OPTIMIZATION := -O0
APP_CFLAGS_DEBUG_LEVEL := -g
```

When your project is fully debugged and ready for release, you might want to enable optimization and omit the symbol table, to achieve faster, smaller executable code. To enable optimization and turn off the symbol table, edit the application makefile to contain the symbol definitions shown in [Example 4-6](#). The absence of a value on the right hand side of the `APP_CFLAGS_DEBUG_LEVEL` definition causes the compiler to omit generating a symbol table.

**Example 4-6.** Application Makefile Settings with Optimization

```
APP_CFLAGS_OPTIMIZATION := -O3
APP_CFLAGS_DEBUG_LEVEL :=
```



When you change compiler options in a makefile, before building the project, run `make clean` to ensure that all sources are recompiled with the correct flags. For further information about makefile editing and `make clean`, refer to “[Applications and Libraries](#)” on page 4-5.

You individually specify the optimization and debug level for the application and BSP projects, and any user library projects you might be using. You use the BSP settings `hal.make.bsp_cflags_debug` and `hal.make.bsp_cflags_optimization` to specify the optimization and debug level in a BSP, as shown in [Example 4-7](#).

**Example 4-7.** Configuring a BSP for Debugging

```
nios2-bsp hal my_bsp --set hal.make.bsp_cflags_debug -g \
--set hal.make.bsp_cflags_optimization -O0
```

Alternatively, you can manipulate the BSP settings with a Tcl script.

You can easily copy an existing BSP and modify it to create a different build configuration. For details, refer to “[Copying, Moving, or Renaming a BSP](#)” on page 4-10.

To change the optimization and debug level for a user library, use the same procedure as for an application.



Normally you must set the optimization and debug levels the same for the application, the BSP, and all user libraries in a software project. If you mix settings, you cannot debug those components which do not have debug settings. For example, if you compile your BSP with the `-O0` flag and without the `-g` flag, you cannot step into the newlib `printf()` function.

## Details of BSP Creation

BSP creation is the same in the Nios II Software Build Tools for Eclipse as at the command line. [Figure 4-1](#) shows how the Software Build Tools create a BSP. The **nios2-bsp-create-settings** utility creates a new BSP settings file. For detailed information about BSP settings files, refer to “[BSP Settings File Creation](#)” on page 4-22.

**nios2-bsp-generate-files** creates the BSP files. The **nios2-bsp-generate-files** utility places all source files in your BSP directory. It copies some files from the Nios II EDS installation directory. Others, such as **system.h** and **Makefile**, it generates dynamically.

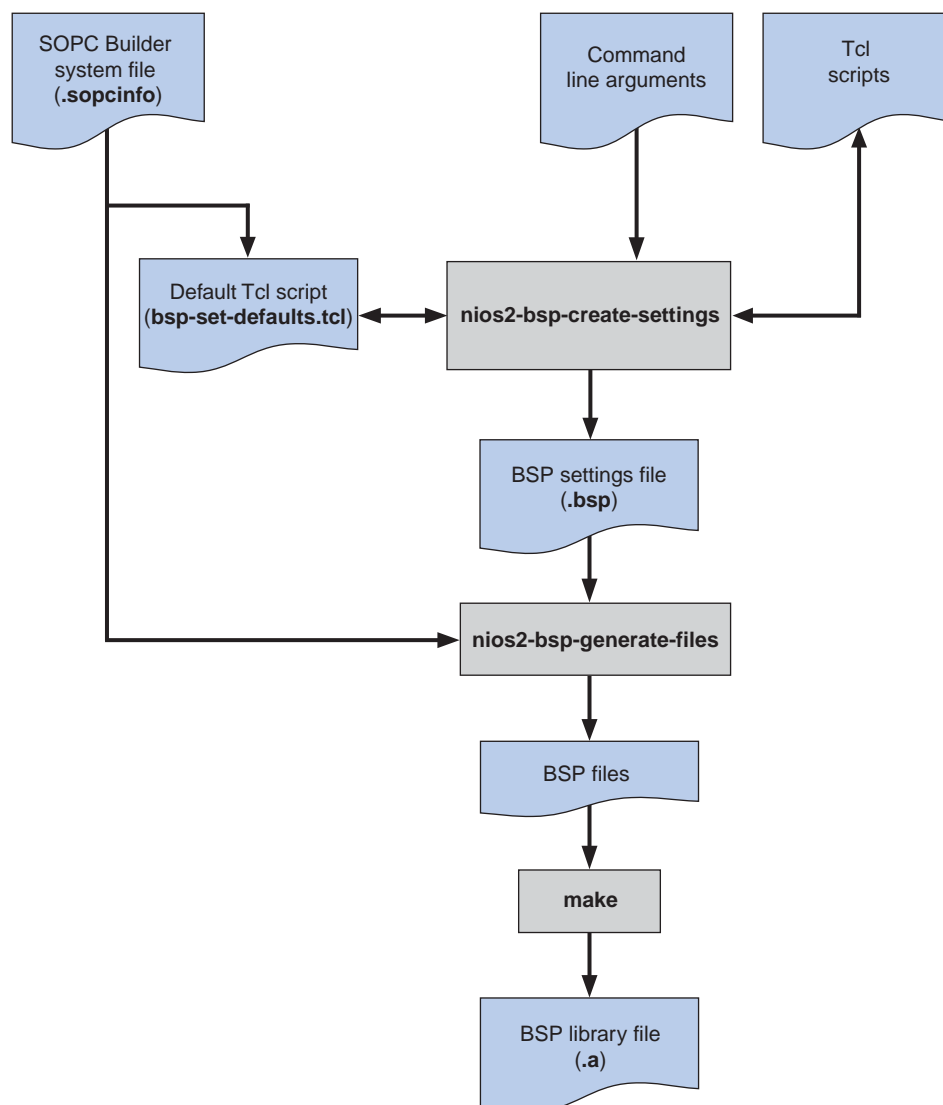


The Software Build Tools manage copied files slightly differently from generated files. If a copied file (such as a HAL source file) already exists, the tools check the file timestamp against the timestamp of the file in the Nios II EDS installation. The tools do not replace the BSP file unless it differs from the distribution file. The tools always overwrite generated files, such as the BSP **Makefile**, **system.h**, and **linker.x**. A comment at the top of each generated file warns you not to edit it.




If you modify a BSP file, it is destroyed when you regenerate the BSP. Avoid modifying BSP files. Use BSP settings, or custom device drivers or software packages, to customize your BSP.

**Figure 4-1.** Nios II Software Build Tools BSP Creation



Nothing prevents you from modifying a BSP generated file. However, after you do so, it becomes difficult to update your BSP to match changes in your SOPC Builder system. If you regenerate your BSP, your previous changes to the generated file are destroyed.

 For information about regenerating your BSP, refer to “Revising Your BSP” on page 4-29.

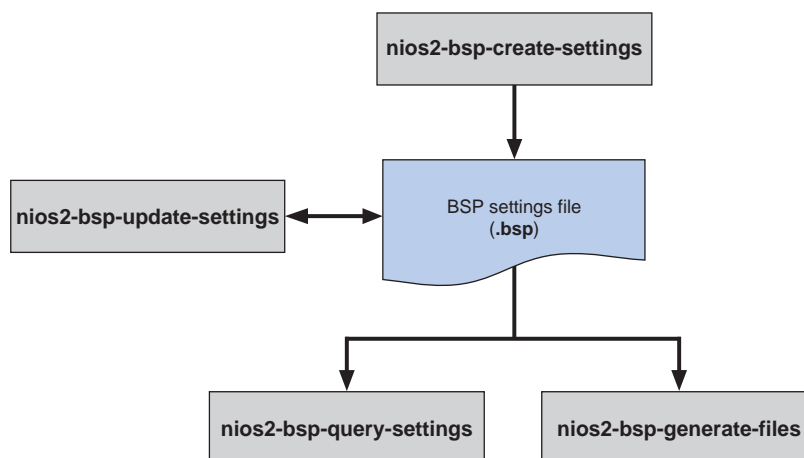
## BSP Settings File Creation

Each BSP has an associated settings file that saves the values of all BSP settings. The BSP settings file is in extensible markup language (XML) format and has a **.bsp** extension by convention. When you create or update your BSP, the Nios II Software Build Tools write the value of all settings to the settings file.

Figure 4-1 on page 4-21 shows that the default Tcl script and **nios2-bsp-generate-files** both use the **.sopcinfo** file. The BSP settings file does not need to duplicate system information (such as base addresses of devices), because the **nios2-bsp-generate-files** utility has access to the **.sopcinfo** file.

Figure 4-2 shows how the Nios II Software Build Tools interact with the BSP settings file. The **nios2-bsp-create-settings** utility creates a new BSP settings file. The **nios2-bsp-update-settings** utility updates an existing BSP settings file. The **nios2-bsp-query-settings** utility reports the setting values in an existing BSP settings file. The **nios2-bsp-generate-files** utility generates a BSP from the BSP settings file.

**Figure 4-2.** BSP Settings File and BSP Utilities



## Generated and Copied Files

To understand how to build and modify Nios II C/C++ projects, it is important to understand the difference between copied and generated files.

A copied file is installed with the Nios II EDS, and copied to your BSP directory when you create your BSP. It does not replace the BSP file unless it differs from the distribution file.

A generated file is dynamically created by the **nios2-bsp-generate-files** utility. Generated files reside in the top-level BSP directory. BSP files are written every time **nios2-bsp-generate-files** is run.

## HAL BSP Files and Folders

The Nios II Software Build Tools create the HAL BSP directory in the location you specify. Figure 4-3 shows a BSP directory after the Software Build Tools create a BSP and generate BSP files. The Software Build Tools place generated files in the top-level BSP directory, and copied files in the **HAL** and **drivers** directories.

**Figure 4-3.** HAL BSP After Generating Files

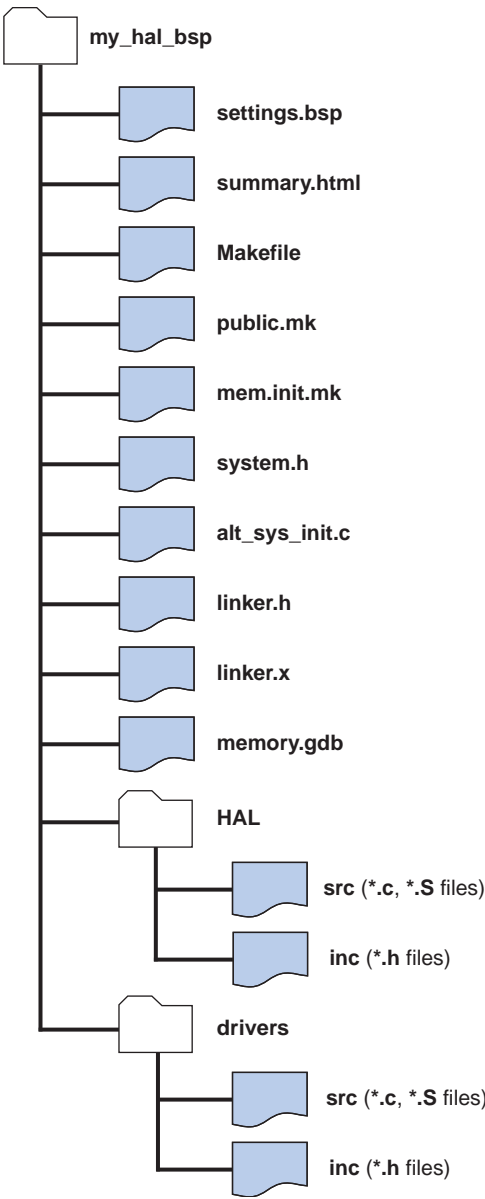


Table 4-6 details all the generated BSP files shown in Figure 4-3.

**Table 4-6.** Generated BSP Files

File Name	Function
<b>settings.bsp</b>	Contains all BSP settings. This file is coded in XML.  On the command line, <b>settings.bsp</b> is created by the <b>nios2-bsp-create-settings</b> command, and optionally updated by the <b>nios2-bsp-update-settings</b> command. The <b>nios2-bsp-query-settings</b> command is available to parse information from the settings file for your scripts. The <b>settings.bsp</b> file is an input to <b>nios2-bsp-generate-files</b> .  The Nios II Software Build Tools for Eclipse provide equivalent functionality.
<b>summary.html</b>	Provides summary documentation of the BSP. You can view <b>summary.html</b> with a hypertext viewer or browser, such as <b>Internet Explorer</b> or <b>Firefox</b> . If you change the <b>settings.bsp</b> file, the Software Build Tools update the <b>summary.html</b> file the next time you regenerate the BSP.
<b>Makefile</b>	Used to build the BSP. The targets you use most often are <b>all</b> and <b>clean</b> . The <b>all</b> target (the default) builds the <b>libhal_bsp.a</b> library file. The <b>clean</b> target removes all files created by a <b>make</b> of the <b>all</b> target.
<b>public.mk</b>	A makefile fragment that provides public information about the BSP. The file is designed to be included in other makefiles that use the BSP, such as application makefiles. The BSP <b>Makefile</b> also includes <b>public.mk</b> .
<b>mem_init.mk</b>	A makefile fragment that defines targets and rules to convert an application executable file to memory initialization files ( <b>.dat</b> , <b>.hex</b> , and <b>.flash</b> ) for HDL simulation, flash programming, and initializable FPGA memories. The <b>mem_init.mk</b> file is designed to be included by an application makefile. For usage, refer to any application makefile generated when you run the Software Build Tools.
<b>alt_sys_init.c</b>	Used to initialize device driver instances and software packages. (1)
<b>system.h</b>	Contains the C declarations describing the BSP memory map and other system information needed by software applications. (1)
<b>linker.h</b>	Contains information about the linker memory layout. <b>system.h</b> includes the <b>linker.h</b> file.
<b>linker.x</b>	Contains a linker script for the GNU linker.
<b>memory.gdb</b>	Contains memory region declarations for the GNU debugger.
<b>obj</b> Directory	Contains the object code files for all source files in the BSP. The hierarchy of the BSP source files is preserved in the <b>obj</b> directory.
<b>libhal_bsp.a</b> Library	Contains the HAL BSP library. All object files are combined in the library file.  The HAL BSP library file is always named <b>libhal_bsp.a</b> .
<b>Note to Table 4-6:</b> (1) For further details about this file, refer to the <i>Developing Programs Using the Hardware Abstraction Layer</i> chapter of the <i>Nios II Software Developer's Handbook</i> .	

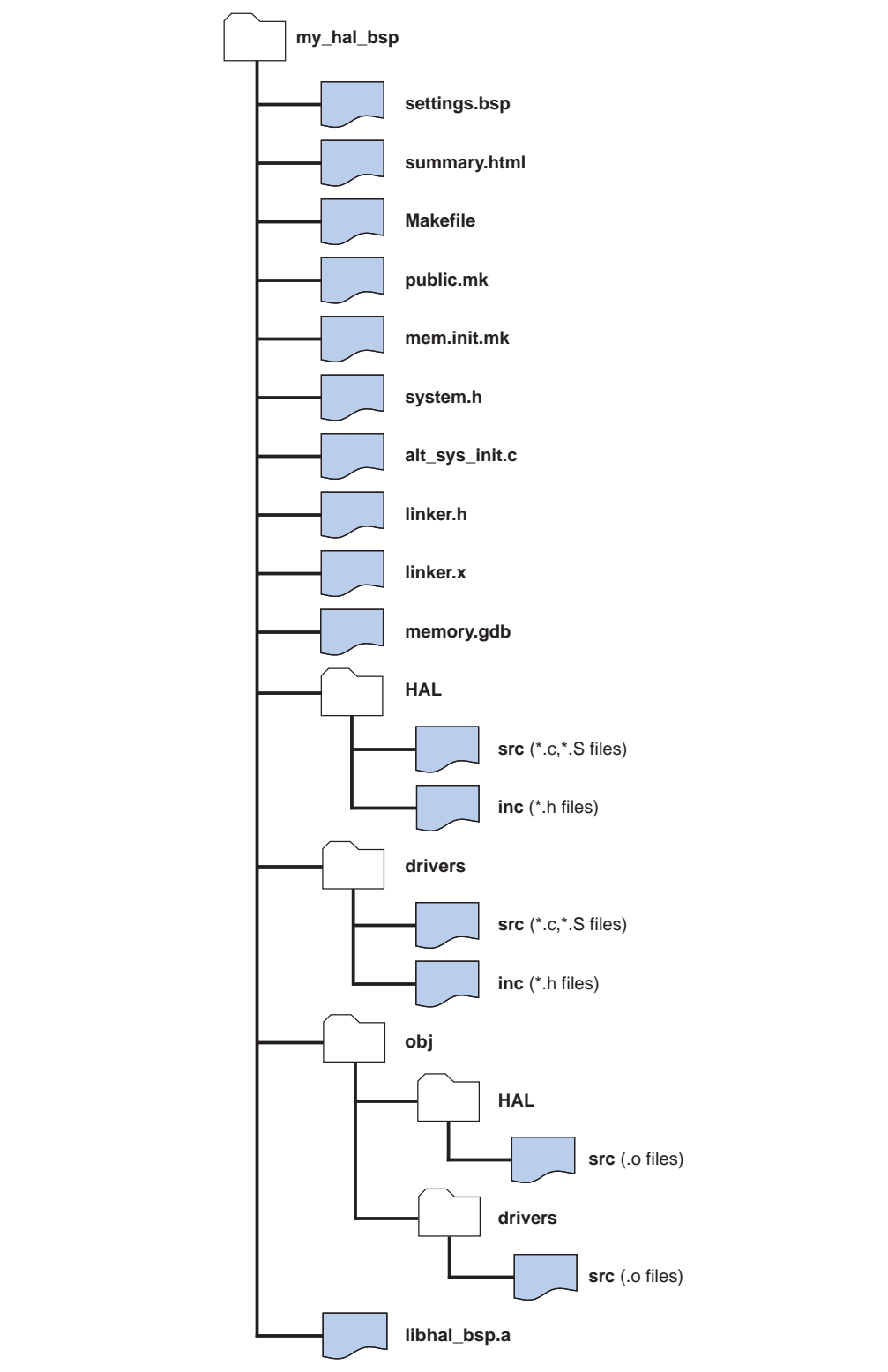
Table 4-7 details all the copied BSP files shown in Figure 4-3.

**Table 4-7.** Copied BSP Files

File Name	Function
<b>HAL</b> Directory	Contains HAL source code files. These are all copied files. The <b>src</b> directory contains the C-language and assembly-language source files. The <b>inc</b> directory contains the header files.  The <b>crt0.S</b> source file, containing HAL C run-time startup code, resides in the <b>HAL/src</b> directory.
<b>drivers</b> Directory	Contains all driver source code. The files in this directory are all copied files. The <b>drivers</b> directory has <b>src</b> and <b>inc</b> subdirectories like the <b>HAL</b> directory.

Figure 4-4 shows a BSP directory after executing **make**.

**Figure 4-4.** HAL BSP After Build



## Linker Map Validation

When a BSP is generated, the Software Build Tools validate the linker region and section mappings, to ensure that they are valid for a HAL project. The tools display an error in each of the following cases:

- The `.entry` section maps to a nonexistent region.
- The `.entry` section maps to a memory region that is less than 32 bytes in length.
- The `.entry` section maps to a memory region that does not start on the reset vector base address.
- The `.exceptions` section maps to a nonexistent region.
- The `.exceptions` section maps to a memory region that does not start on the exception vector base address.
- The `.entry` section and `.exceptions` section map to the same device, and the memory region associated with the `.exceptions` section precedes the memory region associated with the `.entry` section.
- The `.entry` section and `.exceptions` section map to the same device, and the base address of the memory region associated with the `.exceptions` section is less than 32 bytes above the base address of the memory region associated with the `.entry` section.

## Tcl Scripts for BSP Settings

In many cases, you can fully specify your Nios II BSP with the Nios II Software Build Tools settings and defaults. However, in some cases you might need to create some simple Tcl scripts to customize your BSP.

You control the characteristics of your BSP by manipulating BSP settings, using Tcl commands. The most powerful way of using Tcl commands is by combining them in Tcl scripts.

Tcl scripting gives you maximum control over the contents of your BSP. One advantage of Tcl scripts over command-line arguments is that a Tcl script can obtain information from the hardware system or pre-existing BSP settings, and then use it later in script execution.



For descriptions of the Tcl commands used to manipulate BSPs, refer to “Tcl Commands” in the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer’s Handbook*.

## Calling a Custom BSP Tcl Script

From the Nios II Command Shell, you can call a custom BSP Tcl script with any of the following commands:

```
nios2-bsp --script custom_bsp.tcl
nios2-bsp-create-settings --script custom_bsp.tcl
nios2-bsp-query-settings --script custom_bsp.tcl
nios2-bsp-update-settings --script custom_bsp.tcl
```

In the Nios II BSP editor, you can execute a Tcl script when generating a BSP, through the **New BSP Settings File** dialog box.



For information about using Tcl scripts in the Software Build Tools for Eclipse, refer to “Using the BSP Editor” in the *Getting Started with the Graphical User Interface* chapter of the *Nios II Software Developer’s Handbook*.

For an example of custom Tcl script usage, refer to “Creating Memory Initialization Files” on page 4-10.

Any settings you specify in your script override the BSP default values. For further information about BSP defaults, refer to “Specifying BSP Defaults” on page 4-34.



When you update an existing BSP, you must include any scripts originally used to create it. Otherwise, your project’s settings revert to the defaults.



When you use a custom Tcl script to create your BSP, you must include the script in the set of files archived in your version control system. For further information, refer to “Using Version Control” on page 4-9.

The Tcl script in [Example 4-8](#) is a very simple example that sets `stdio` to a device with the name `my_uart`.

---

**Example 4-8.** Simple Tcl script

---

```
set default_stdio my_uart
set_setting hal.stdin $default_stdio
set_setting hal.stdout $default_stdio
set_setting hal.stderr $default_stdio
```

---

[Example 4-9](#) illustrates how you might use more powerful scripting capabilities to customize a BSP based on the contents of the SOPC Builder system.

**Example 4-9.** Tcl Script to Examine Hardware and Choose Settings

---

```

# Select a device connected to the processor as the default STDIO device.

# It returns the slave descriptor of the selected device.
# It gives first preference to devices with stdio in the name.
# It gives second preference to JTAG UARTs.
# If no JTAG UARTs are found, it uses the last character device.
# If no character devices are found, it returns "none".

# Procedure that does all the work of determining the stdio device
proc choose_default_stdio {} {
    set last_stdio "none"
    set first_jtag_uart "none"

    # Get all slaves attached to the processor.
    set slave_descs [get_slave_descs]

    foreach slave_desc $slave_descs {
        # Lookup module class name for slave descriptor.
        set module_name [get_module_name $slave_desc]
        set module_class_name [get_module_class_name $module_name]

        # If the module_name contains "stdio", we'll choose it
        # and return immediately.
        if { [regexp .*stdio.* $module_name] } {
            return $slave_desc
        }

        # Assume it is a JTAG UART if the module class name contains
        # the string "jtag_uart". In that case, return the first one
        # found.
        if { [regexp .*jtag_uart.* $module_class_name] } {
            if { $first_jtag_uart == "none" } {
                set first_jtag_uart $slave_desc
            }
        }

        # Track last character device in case no JTAG UARTs found.
        if { [is_char_device $slave_desc] } {
            set last_stdio $slave_desc
        }
    }

    if { $first_jtag_uart != "none" } {
        return $first_jtag_uart
    }

    return $last_stdio
}

# Call routine to determine stdio
set default_stdio [choose_default_stdio]

# Set stdio settings to use results of above call.
set_setting hal.stdin $default_stdio
set_setting hal.stdout $default_stdio
set_setting hal.stderr $default_stdio

```

---





The Nios II Software Build Tools use slave descriptors to refer to components connected to the Nios II processor. A slave descriptor is the unique name of an SOPC Builder component's slave port.

If a component has only one slave port connected to the Nios II processor, the slave descriptor is the same as the name of the component (for example, `onchip_mem_0`). If a component has multiple slave ports connecting the Nios II to multiple resources in the component, the slave descriptor is the name of the component followed by an underscore and the slave port name (for example, `onchip_mem_0_s1`).



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

The script shown in [Example 4-9](#) is similar to `bsp-stdio-utils.tcl`, which examines the hardware system and determines what device to use for `stdio`. For details, refer to [“Specifying BSP Defaults” on page 4-34](#).

## Revising Your BSP

Your BSP is customized to your hardware design and your software requirements. If your hardware design or software requirements change, you usually need to revise your BSP.

Every BSP is based on a Nios II processor in an SOPC Builder system. The BSP settings file does not duplicate information available in the `.sopcinfo` file, but it does contain system-dependent settings that reference system information. Because of these system-dependent settings, a BSP settings file can become inconsistent with its system if the system changes.

You can revise a BSP at several levels. This section describes each level, and provides guidance about when to use it.

### Rebuilding Your BSP

Rebuilding a BSP is the most superficial way to revise a BSP.

#### What Happens

Rebuilding the BSP simply recreates all BSP object files and the `.a` library file. BSP settings, source files, and compiler options are unchanged.

#### How to Rebuild Your BSP

In the Nios II Software Build Tools for Eclipse, right-click the BSP project and click **Build**.

On the command line, change to the BSP directory and type `make`.

### Regenerating Your BSP

Regenerating the BSP refreshes the BSP source files without updating the BSP settings.

## What Happens

Regenerating a BSP has the following effects:

- Ensures that the correct set of BSP files is present, as follows:
  - Copies all required source files to the BSP directory tree. Copied BSP files are listed in [Table 4-7 on page 4-24](#).  
If a copied file (such as a HAL source file) already exists, the Software Build Tools check the file timestamp against the timestamp of the file in the Nios II EDS installation. The tools do not replace the BSP file unless it differs from the distribution file.
  - Recreates all generated files. Generated BSP files are listed in [Table 4-6 on page 4-24](#).
  - Removes any files that are not required, for example, sources for drivers that are no longer in use.



If you modify a BSP file, it is destroyed when you regenerate the BSP. Avoid modifying BSP files. Use BSP settings, or custom device drivers or software packages, to customize your BSP.

- Reads the **.sopcinfo** file for basic system parameters such as module base addresses and clock frequencies.
- Retrieves the current system identification (ID) from the **.sopcinfo** file. Ensures that the correct system ID is inserted in the **.elf** file the next time the BSP is built.
- Retains existing settings in the BSP settings file.



The Software Build Tools do not ensure that the settings are consistent with the hardware design in the **.sopcinfo** file.

## When to Regenerate Your BSP

Regenerating your BSP is required (and sufficient) in the following circumstances:

- You change your hardware design, but all BSP system-dependent settings remain consistent with the new **.sopcinfo** file. The following are examples of system changes that do not affect BSP system-dependent settings:
  - Changing a component's base address
  - With the internal interrupt controller (IIC), adding or removing hardware interrupts
  - With the IIC, changing a hardware interrupt number
  - Changing a clock frequency
  - Changing a simple processor option, such as cache size or core type
  - Changing a simple component option, other than memory size.
  - Adding a bridge
  - Adding a new component
  - Removing or renaming a component, other than a memory component, the `stdio` device, or the system timer device



Unless you are sure that your modified hardware design remains consistent with your BSP settings, regenerate your BSP as described in *“Updating Your BSP”* on page 4-31.

- You want to eliminate any customized source files and revert to the distributed BSP code.
- You have installed a new version of the Nios II EDS, and you want the updated BSP software implementations.
- When you attempt to rebuild your project, an error message indicates that the BSP must be updated.
- You have updated or recreated the BSP settings file.

### How to Regenerate Your BSP

You can regenerate your BSP in the Nios II Software Build Tools for Eclipse, or with Software Build Tools commands at the command line.

#### Regenerating Your BSP in Eclipse

In the Nios II Software Build Tools for Eclipse, right-click the BSP project, point to **Nios II**, and click **Generate BSP**.



For information about generating a BSP with the Software Build Tools for Eclipse, refer to the *Getting Started with the Graphical User Interface* chapter of the *Nios II Software Developer's Handbook*.

#### Regenerating Your BSP from the Command Line

From the command line, use the **nios2-bsp-generate-files** command.



For information about the **nios2-bsp-generate-files** command, refer to the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*.

## Updating Your BSP

When you update a BSP, you recreate the BSP settings file based on the current hardware definition and previous BSP settings.



You must always regenerate your BSP after updating the BSP settings file.

### What Happens

Updating a BSP has the following effects:

- System-dependent settings are derived from the original BSP settings file, but adjusted to correspond with any changes in the SOPC Builder system.
- Non-system-dependent BSP settings persist from the original BSP settings file.



Also refer to *“Regenerating Your BSP”* on page 4-29 for actions taken when you regenerate the BSP after updating it.

## When to Update Your BSP

Updating your BSP is necessary in the following circumstances:

- A change to your BSP settings is required.
- Changes to your **.sopcinfo** file make it inconsistent with your BSP. The following are examples of system changes that affect BSP system-dependent settings:
  - Renaming the processor
  - Renaming or removing a memory, the `stdio` device, or the system timer device
  - Changing a memory size
  - Changing the processor reset or exception slave port or offset
  - Adding or removing an external interrupt controller (EIC)
  - Changing the parameters of an EIC
- When you attempt to rebuild your project, an error message indicates that you must update the BSP.

## How to Update Your BSP

You can update your BSP at the command line. You have the option to use a Tcl script to control your BSP settings.

From the command line, use the **nios2-bsp-update-settings** command. You can use the `--script` option to define the BSP with a Tcl script.



For details about the **nios2-bsp-update-settings** command, refer to the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*.

**nios2-bsp-update-settings** does not reapply default settings unless you explicitly call the top-level default Tcl script with the `--script` option.



For information about using the default Tcl script, refer to “*Specifying BSP Defaults*” on page 4-34.

Alternatively, you can update your BSP with the **nios2-bsp** script. **nios2-bsp** determines that your BSP already exists, and uses the **nios2-bsp-update-settings** command to update the BSP settings file.

The **nios2-bsp** script executes the default Tcl script every time it runs, overwriting previous default settings. If you want to preserve all settings, including the default settings, use the `DONT_CHANGE` keyword, described in “*Top Level Tcl Script for BSP Defaults*” on page 4-35. Alternatively, you can provide **nios2-bsp** with command-line options or Tcl scripts to override the default settings.



For information about using the **nios2-bsp** script, refer to the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*.

## Recreating Your BSP

When you recreate your BSP, you start over as if you were creating a new BSP.



After you recreate your BSP, you must always regenerate it.

### What Happens

Recreating a BSP has the following effects:

- System-dependent settings are created based on the current SOPC Builder system.
- Non-system-dependent settings are can be selected by the default Tcl script, by values you specify, or both.

Also refer to [“Regenerating Your BSP” on page 4-29](#) for actions taken when you generate the BSP after recreating it.

### When to Recreate Your BSP

If you are working exclusively in the Nios II Software Build Tools for Eclipse, and you modify the underlying hardware design, the best practice is to create a new BSP.

Creating a BSP is very easy with the Software Build Tools for Eclipse. Manually correcting a large number of interrelated settings, on the other hand, can be difficult.

### How to Recreate Your BSP

You can recreate your BSP in the Nios II Software Build Tools for Eclipse, or using the Software Build Tools at the command line. Regardless which method you choose, you can use Tcl scripts to control and reproduce your BSP settings. This section describes the options for recreating BSPs.

### Using Tcl Scripts When Recreating Your BSP

A Tcl script automates selection of BSP settings. This automation ensures that you can reliably update or recreate your BSP with its original settings. Except when creating very simple BSPs, Altera recommends specifying all BSP settings with a Tcl script.

To use Tcl scripts most effectively, it is best to create a Tcl script at the time you initially create the BSP. However, the BSP Editor enables you to export a Tcl script from an existing BSP.



For details about exporting Tcl scripts, refer to “Using the BSP Editor” in the [Getting Started with the Graphical User Interface](#) chapter of the *Nios II Software Developer’s Handbook*.

By recreating the BSP settings file with a Tcl script that specifies all BSP settings, you can reproduce the original BSP while ensuring that system-dependent settings are adjusted correctly based on any changes in the SOPC Builder system.



For information about Tcl scripting with the Software Build Tools, refer to [“Tcl Scripts for BSP Settings” on page 4-26](#).

### Recreating Your BSP in Eclipse

The process for recreating a BSP is the same as the process for creating a new BSP. The Nios II Software Build Tools for Eclipse provides an option to import a Tcl script when creating a BSP.



For details, refer to “Getting Started” and “Using the BSP Editor” in the [Getting Started with the Graphical User Interface](#) chapter of the *Nios II Software Developer’s Handbook*.

### Recreating Your BSP at the Command Line

Recreate your BSP using the **nios2-bsp-create-settings** command. You can use the **--script** option to define the BSP with a Tcl script.

The **nios2-bsp-create-settings** command does not apply default settings to your BSP. However, you can use the **--script** command-line option to run the default Tcl script. For information about the default Tcl script, refer to [“Specifying BSP Defaults”](#).



For information about using the **nios2-bsp-create-settings** command, refer to the [Nios II Software Build Tools Reference](#) chapter of the *Nios II Software Developer's Handbook*.

## Specifying BSP Defaults

The Nios II Software Build Tools set BSP defaults using a set of Tcl scripts. [Table 4–8](#) lists the components of the BSP default Tcl scripts included in the Nios II Software Build Tools. These scripts specify default BSP settings. The scripts are located in the following directory:

`<Nios II EDS install path>/sdk2/bin`



For more information about Tcl scripting with the Software Build Tools, refer to [“Tcl Scripts for BSP Settings”](#) on page 4–26.

**Table 4–8.** Default Tcl Script Components

Script	Level	Summary
<b>bsp-set-defaults.tcl</b>	Top-level	Sets system-dependent settings to default values.
<b>bsp-call-proc.tcl</b>	Top-level	Calls a specified procedure in one of the helper scripts.
<b>bsp-stdio-utils.tcl</b>	Helper	Specifies <code>stdio</code> device settings.
<b>bsp-timer-utils.tcl</b>	Helper	Specifies system timer device setting.
<b>bsp-linker-utils.tcl</b>	Helper	Specifies memory regions and section mappings for linker script.
<b>bsp-bootloader-utils.tcl</b>	Helper	Specifies boot loader-related settings.

The Nios II Software Build Tools use the default Tcl scripts to specify default values for system-dependent settings. System-dependent settings are BSP settings that reference system information in the **.sopcinfo** file.

The software build tools execute the default Tcl script before any user-specified Tcl scripts. As a result, user input overrides settings made by the default Tcl script.

You can pass command-line options to the default Tcl script to override the choices it makes or to prevent it from making changes to settings. For details, refer to [“Top Level Tcl Script for BSP Defaults”](#).

The default Tcl script makes the following choices for you based on your SOPC Builder system:

- `stdio` character device
- System timer device
- Default linker memory regions

- Default linker sections mapping
- Default boot loader settings

The default Tcl scripts use slave descriptors to assign devices.

## Top Level Tcl Script for BSP Defaults

The top level Tcl script for setting BSP defaults is **bsp-set-defaults.tcl**. This script specifies BSP system-dependent settings, which depend on the SOPC Builder system. The **nios2-bsp-create-settings** and **nios2-bsp-update-settings** utilities do not call the default Tcl script when creating or updating a BSP settings file. The `--script` option must be used to specify **bsp-set-defaults.tcl** explicitly. Both the Nios II Software Build Tools for Eclipse and the **nios2-bsp** script call the default Tcl script by invoking either **nios2-bsp-create-settings** or **nios2-bsp-update-settings** with the `--script bsp-set-defaults.tcl` option.

The default Tcl script consists of a top-level Tcl script named **bsp-set-defaults.tcl** plus the helper Tcl scripts listed in Table 4–8. The helper Tcl scripts do the real work of examining the **.sopcinfo** file and choosing appropriate defaults.

The **bsp-set-defaults.tcl** script sets the following defaults:

- `stdio` character device (**bsp-stdio-utils.tcl**)
- System timer device (**bsp-timer-utils.tcl**)
- Default linker memory regions (**bsp-linker-utils.tcl**)
- Default linker sections mapping (**bsp-linker-utils.tcl**)
- Default boot loader settings (**bsp-bootloader-utils.tcl**)

You run the default Tcl script on the **nios2-bsp-create-settings**, **nios2-bsp-query-settings**, or **nios2-bsp-update-settings** command line, by using the `--script` argument. It has the following usage:

```
bsp-set-defaults.tcl [<argument name> <argument value>]*
```

Table 4–9 lists default Tcl script arguments in detail. All arguments are optional. If present, each argument must be in the form of a name and argument value, separated by white space. All argument values are strings. For any argument not specified, the corresponding helper script chooses a suitable default value. In every case, if the argument value is `DONT_CHANGE`, the default Tcl scripts leave the setting unchanged. The `DONT_CHANGE` value allows fine-grained control of what settings the default Tcl script changes and is useful when updating an existing BSP.

**Table 4–9.** Default Tcl Script Command-Line Options (Part 1 of 2)

Argument Name	Argument Value
<code>default_stdio</code>	Slave descriptor of default <code>stdio</code> device ( <code>stdin</code> , <code>stdout</code> , <code>stderr</code> ). Set to <code>none</code> if no <code>stdio</code> device desired.
<code>default_sys_timer</code>	Slave descriptor of default system timer device. Set to <code>none</code> if no system timer device desired.



**Table 4-9.** Default Tcl Script Command-Line Options (Part 2 of 2)

Argument Name	Argument Value
default_memory_regions	Controls generation of memory regions. By default, <b>bsp-linker-utils.tcl</b> removes and regenerates all current memory regions. Use the <code>DONT_CHANGE</code> keyword to suppress this behavior.
default_sections_mapping	Slave descriptor of the memory device to which the default sections are mapped. This argument has no effect if <code>default_memory_regions == DONT_CHANGE</code> .
enable_bootloader	Boolean: 1 if a boot loader is present; 0 otherwise.

## Specifying the Default stdio Device

The **bsp-stdio-utils.tcl** script provides procedures to choose a default `stdio` slave descriptor and to set the `hal.stdin`, `hal.stdout`, and `hal.stderr` BSP settings to that value.



For more information about these settings, refer to the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*.

The script searches the **.sopcinfo** file for a slave descriptor with the string `stdio` in its name. If **bsp-stdio-utils.tcl** finds any such slave descriptors, it chooses the first as the default `stdio` device. If the script finds no such slave descriptor, it looks for a slave descriptor with the string `jtag_uart` in its component class name. If it finds any such slave descriptors, it chooses the first as the default `stdio` device. If the script finds no slave descriptors fitting either description, it chooses the last character device slave descriptor connected to the Nios II processor. If **bsp-stdio-utils.tcl** does not find any character devices, there is no `stdio` device.

## Specifying the Default System Timer

The **bsp-timer-utils.tcl** script provides procedures to choose a default system timer slave descriptor and to set the `hal.sys_clk_timer` BSP setting to that value.



For more information about this setting, refer to the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*.

The script searches the **.sopcinfo** file for a timer component to use as the default system timer. To be an appropriate system timer, the component must have the following characteristics:

- It must be a timer, that is, `is_timer_device` must return true.
- It must have a slave port connected to the Nios II processor.

When the script finds an appropriate system timer component, it sets `hal.sys_clk_timer` to the timer slave port descriptor. The script prefers a slave port whose descriptor contains the string `sys_clk`, if one exists. If no appropriate system timer component is found, the script sets `hal.sys_clk_timer` to none.



## Specifying the Default Memory Map

The **bsp-linker-utils.tcl** script provides procedures to add the default linker script memory regions and map the default linker script sections to a default region. The **bsp-linker-utils.tcl** script uses the `add_memory_region` and `add_section_mapping` BSP Tcl commands.



For more information about these commands, refer to the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*.

The script chooses the largest volatile memory region as the default memory region. If there is no volatile memory region, **bsp-linker-utils.tcl** chooses the largest non-volatile memory region. The script assigns the `.text`, `.rodata`, `.rdata`, `.bss`, `.heap`, and `.stack` section mappings to this default memory region. The script also sets the `hal.linker.exception_stack_memory_region` BSP setting to the default memory region. The setting is available in case the separate exception stack option is enabled (this setting is disabled by default).



For more information about this setting, refer to the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*.

## Specifying Default Bootloader Parameters

The **bsp-bootloader-utils.tcl** script provides procedures to specify the following BSP boolean settings:

- `hal.linker.allow_code_at_reset`
- `hal.linker.enable_alt_load_copy_rodata`
- `hal.linker.enable_alt_load_copy_rdata`
- `hal.linker.enable_alt_load_copy_exceptions`



For more information about these settings, refer to the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*.

The script examines the `.text` section mapping and the Nios II reset slave port. If the `.text` section is mapped to the same memory as the Nios II reset slave port and the reset slave port is a flash memory device, the script assumes that a boot loader is being used. You can override this behavior by passing the `enable_bootloader` option to the default Tcl script.

Table 4-10 shows how the **bsp-bootloader-utils.tcl** script specifies the value of boot loader-dependent settings. If a boot loader is enabled, the assumption is that the boot loader is located at the reset address and handles the copying of sections on reset. If there is no boot loader, the BSP might need to provide code to handle these functions. You can use the `alt_load()` function to implement a boot loader.

**Table 4-10.** Boot Loader-Dependent Settings

Setting name (1)	Value When Boot Loader Enabled	Value When Boot Loader Disabled
<code>hal.linker.allow_code_at_reset</code>	0	1
<code>hal.linker.enable_alt_load_copy_rodata</code>	0	1 if <code>.rodata</code> memory different than <code>.text</code> memory and <code>.rodata</code> memory is volatile; 0 otherwise
<code>hal.linker.enable_alt_load_copy_rwdata</code>	0	1 if <code>.rwdata</code> memory different than <code>.text</code> memory; 0 otherwise
<code>hal.linker.enable_alt_load_copy_exceptions</code>	0	1 if <code>.exceptions</code> memory different than <code>.text</code> memory and <code>.exceptions</code> memory is volatile; 0 otherwise

**Notes to Table 4-10:**

- (1) For further information about these settings, refer to the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*.

## Using Individual Default Tcl Procedures

The default Tcl script consists of the top-level **bsp-call-proc.tcl** script plus the helper scripts listed in [Table 4-8 on page 4-34](#). The procedure call Tcl script allows you to call a specific procedure in the helper scripts, if you want to invoke some of the default Tcl functionality without running the entire default Tcl script.

The procedure call Tcl script has the following usage:

```
bsp-call-proc.tcl <proc-name> [<args>]*
```

**bsp-call-proc.tcl** calls the specified procedure with the specified (optional) arguments. Refer to the default Tcl scripts to view the available functions and their arguments. The **bsp-call-proc.tcl** script includes the same files as the **bsp-set-defaults.tcl** script, so any function in those included files is available.

## Device Drivers and Software Packages

The Nios II Software Build Tools can incorporate device drivers and software packages supplied by Altera, supplied by other third-party developers, or created by you.



For details about integrating device drivers and software packages with the Nios II Software Build Tools, refer to the *Developing Device Drivers for the Hardware Abstraction Layer* chapter of the *Nios II Software Developer's Handbook*.


## Boot Configurations

The HAL and MicroC/OS-II BSPs support several boot configurations. The default Tcl script configures an appropriate boot configuration based on your SOPC Builder system and other settings.

 For detailed information about the HAL boot loader process, refer to the *Developing Programs Using the Hardware Abstraction Layer* chapter of the *Nios II Software Developer's Handbook*.

Table 4-11 shows the memory types that the default Tcl script recognizes when making decisions about your boot configuration. The default Tcl script uses the `IsFlash` and `IsNonVolatileStorage` properties to determine what kind of memory is in the system.

The `IsFlash` property of the memory module (defined in the `.sopcinfo` file) indicates whether the `.sopcinfo` file identifies the memory as a flash memory device. The `IsNonVolatileStorage` property indicates whether the `.sopcinfo` file identifies the memory as a non-volatile storage device. The contents of a non-volatile memory device are fixed and always present.

 Some FPGA memories can be initialized when the FPGA is configured. They are not considered non-volatile because the default Tcl script has no way to determine whether they are actually initialized in a particular system.

**Table 4-11.** Memory Types

Memory Type	Examples	IsFlash	IsNonVolatileStorage
Flash	Common flash interface (CFI), erasable programmable configurable serial (EPCS) device	true	true
ROM	On-chip memory configured as ROM, HardCopy ROM	false	true
RAM	On-chip memory configured as RAM, HardCopy RAM, SDRAM, synchronous static RAM (SSRAM)	false	false

The following sections describe each supported build configuration in detail. The `alt_load()` facility is HAL code that optionally copies sections from the boot memory to RAM. You can set an option to enable the boot copy. This option only adds the code to your BSP if it needs to copy boot segments. The `hal.enable_alt_load` setting enables `alt_load()` and there are settings for each of the three sections it can copy (such as `hal.enable_alt_load_copy_rodata`). Enabling `alt_load()` also modifies the memory layout specified in your linker script.

## Boot from Flash Configuration

The reset address points to a boot loader in a flash memory. The boot loader initializes the instruction cache, copies each memory section to its virtual memory address (VMA), and then jumps to start.

This boot configuration has the following characteristics:

- `alt_load()` not called
- No code at reset in executable file

The default Tcl script chooses this configuration when the memory associated with the processor reset address is a flash memory and the `.text` section is mapped to a different memory (for example, SDRAM).

Altera provides example boot loaders for CFI and EPCS memory in the Nios II EDS, precompiled to Motorola S-record Files (**.srec**). You can use one of these example boot loaders, or provide your own.

## Boot from Monitor Configuration

The reset address points to a monitor in a nonvolatile ROM or initialized RAM. The monitor initializes the instruction cache, downloads the application memory image (for example, using a UART or Ethernet connection), and then jumps to the entry point provided in the memory image.

This boot configuration has the following characteristics:

- `alt_load()` not called
- No code at reset in executable file

The default Tcl script assumes no boot loader is in use, so it chooses this configuration only if you enable it. To enable this configuration, pass the following argument to the default Tcl script:

```
enable_bootloader 1
```

If you are using the **nios2-bsp** script, call it as follows:

```
nios2-bsp hal my_bsp --use_bootloader 1 ←
```

## Run from Initialized Memory Configuration

The reset address points to the beginning of the application in memory (no boot loader). The reset memory must have its contents initialized before the processor comes out of reset. The initialization might be implemented by using a non-volatile reset memory (for example, flash, ROM, initialized FPGA RAM) or by an external master (for example, another processor) that writes the reset memory. The HAL C run-time startup code (`crt0`) initializes the instruction cache, uses `alt_load()` to copy select sections to their VMAs, and then jumps to `_start`. For each associated section (`.rwdata`, `.rodata`, `.exceptions`), boolean settings control this behavior. The default Tcl scripts set these to default values as described in [Table 4-10 on page 4-38](#).

`alt_load()` must copy the `.rwdata` section (either to another RAM or to a reserved area in the same RAM as the `.text` RAM) if `.rwdata` needs to be correct after multiple resets.

This boot configuration has the following characteristics:

- `alt_load()` called
- Code at reset in executable file

The default Tcl script chooses this configuration when the reset and `.text` memory are the same.

## Run-time Configurable Reset Configuration

The reset address points to a memory that contains code that executes before the normal reset code. When the processor comes out of reset, it executes code in the reset memory that computes the desired reset address and then jumps to it. This boot configuration allows a processor with a hard-wired reset address to appear to reset to a programmable address.

This boot configuration has the following characteristics:

- `alt_load()` might be called (depends on boot configuration)
- No code at reset in executable file

Because the processor reset address points to an additional memory, the algorithms used by the default Tcl script to select the appropriate boot configuration might make the wrong choice. The individual BSP settings specified by the default Tcl script need to be explicitly controlled.

## Altera-Provided Development Tools

This section lists the components of the Nios II Software Build Tools, and other development tools that Altera provides for use with the Software Build Tools. This section does not describe detailed usage of the tools, but refers you to the most appropriate documentation.

### Nios II Software Build Tool GUIs

The Nios II EDS provides the following software build tools GUIs for software development:

- The Nios II Software Build Tools for Eclipse
- The Nios II BSP Editor
- The Nios II Flash Programmer

Each GUI is primarily a thin layer providing graphical control of the command-line tools described in [“The Nios II Command-Line Commands”](#) on page 4-43.



Refer to [Appendix A. Using the Nios II Integrated Development Environment](#) in the *Nios II Software Developer's Handbook* for a description of the Nios II Integrated Development Environment (IDE).

[Table 4-12](#) outlines the correlation between GUI features and the Software Build Tools command line.

**Table 4-12.** Summary of Nios II GUI Tasks (Part 1 of 2)

Task	Tool	Feature	Nios II Software Build Tools Command Line
Creating an example Nios II program	Nios II Software Build Tools for Eclipse	<b>Nios II Application and BSP from Template</b> wizard	<code>create-this-app</code> script
Creating an application	Nios II Software Build Tools for Eclipse	<b>Nios II Application</b> wizard	<code>nios2-app-generate-makefile</code> utility

**Table 4-12.** Summary of Nios II GUI Tasks (Part 2 of 2)

Task	Tool	Feature	Nios II Software Build Tools Command Line
Creating a user library	Nios II Software Build Tools for Eclipse	<b>Nios II Library</b> wizard	<b>nios2-lib-generate-makefile</b> utility
Creating a BSP	Nios II Software Build Tools for Eclipse	<b>Nios II Board Support Package</b> wizard	<ul style="list-style-type: none"> <li>■ Simple: <ul style="list-style-type: none"> <li>■ <b>nios2-bsp</b> script</li> </ul> </li> <li>■ Detailed: <ul style="list-style-type: none"> <li>■ <b>nios2-bsp-create-settings</b> utility</li> <li>■ <b>nios2-bsp-generate-files</b> utility</li> </ul> </li> </ul>
	BSP Editor	<b>New BSP Setting File</b> dialog box	
Modifying an application	Nios II Software Build Tools for Eclipse	<b>Nios II Application Properties</b> page	<b>nios2-app-update-makefile</b> utility
Modifying a user library	Nios II Software Build Tools for Eclipse	<b>Nios II Library Properties</b> page	<b>nios2-lib-update-makefile</b> utility
Updating a BSP	Nios II Software Build Tools for Eclipse	<b>Nios II BSP Properties</b> page	<b>nios2-bsp-update-settings</b> utility <b>nios2-bsp-generate-files</b> utility
	BSP Editor	—	
Examining properties of a BSP	Nios II Software Build Tools for Eclipse	<b>Nios II BSP Properties</b> page	<b>nios2-bsp-query-settings</b> utility
	BSP Editor	—	
Programming flash memory	Nios II Flash Programmer	—	<b>nios2-flash-programmer</b>
Importing a command-line project	Nios II Software Build Tools for Eclipse	<b>Import</b> dialog box	—

### The Nios II Software Build Tools for Eclipse

The Nios II Software Build Tools for Eclipse are a configuration of the popular Eclipse development environment, specially adapted to the Nios II family of embedded processors. The Nios II Software Build Tools for Eclipse include Nios II plugins for access to the Nios II Software Build Tools, enabling you to create applications based on the Altera HAL, and debug them using the JTAG debugger.

You can launch the Nios II Software Build Tools for Eclipse either of the following ways:

- In the Windows operating system, on the Start menu, point to **Programs > Altera > Nios II EDS <version>**, and click **Nios II <version> Software Build Tools for Eclipse**.
- From the Nios II Command Shell, by typing `eclipse-nios2`.



For more information about the Nios II Software Build Tools for Eclipse, refer to the *Getting Started with the Graphical User Interface* chapter of the *Nios II Software Developer's Handbook*.

## The Nios II BSP Editor

You can create or modify a Nios II BSP project with the Nios II BSP Editor, a standalone GUI that also works with the Nios II Software Build Tools for Eclipse. You can launch the BSP Editor either of the following ways:

- From the Nios II menu in the Nios II Software Build Tools for Eclipse
- From the Nios II Command Shell, by typing **nios2-bsp-editor**.

The Nios II BSP Editor enables you to edit settings, linker regions, and section mappings, and to select software packages and device drivers.

The capabilities of the Nios II BSP Editor constitute a large subset of the capabilities of the **nios2-bsp-create-settings**, **nios2-bsp-update-settings**, and **nios2-bsp-generate-files** utilities. Any project created in the BSP Editor can also be created using the command-line utilities.



For more information about the BSP Editor, refer to “Using the BSP Editor” in the *Getting Started with the Graphical User Interface* chapter of the *Nios II Software Developer’s Handbook*.

## The Nios II Flash Programmer

The Nios II flash programmer allows you to program flash memory devices on a target board. The flash programmer supports programming flash on any board, including Altera development boards and your own custom boards. The flash programmer facilitates programming flash for the following purposes:

- Executable code and data
- Bootstrap code to copy code from flash to RAM, and then run from RAM
- HAL file subsystems
- FPGA hardware configuration data

You can launch the flash programmer either of the following ways:

- From the Nios II menu in the Nios II Software Build Tools for Eclipse
- From the Nios II Command Shell, by typing:

```
nios2-flash-programmer-generate↵
```

## The Nios II Command-Line Commands

This section describes the Altera Nios II command-line tools. You can run these tools from the Nios II Command Shell.



For information about launching the Nios II Command Shell, refer to the *Getting Started from the Command Line* chapter of the *Nios II Software Developer’s Handbook*.

Each tool provides its own documentation in the form of help accessible from the command line. To view the help, open the Nios II Command Shell, and type the following command:

```
<name of tool> --help↵
```

## GNU Compiler Tool Chain

The Nios II compiler tool chain is based on the standard GNU gcc compiler, assembler, linker, and make facilities. Altera provides and supports the standard GNU compiler tool chain for the Nios II processor. The GNU tools are under the *<Nios II EDS install path>/bin/nios2-gnutools* directory.

GNU tools for the Nios II processor are generally named **nios2-elf-*<tool name>***. The following list shows some examples:

- **nios2-elf-gcc**
- **nios2-elf-as**
- **nios2-elf-ld**
- **nios2-elf-objdump**
- **nios2-elf-size**

The exception is the **make** utility, which is simply named **make**.



For a comprehensive list of Nios II GNU tools, refer to the GNU HTML documentation, available at the [Nios II Embedded Design Suite Support](#) page of the Altera website. You can obtain further information about GNU from the Free Software Foundation website ([www.gnu.org](http://www.gnu.org)).



These tools are also used with the Nios II IDE.

## Nios II Software Build Tools

The Nios II Software Build Tools utilities and scripts provide the functionality underlying the Nios II Software Build Tools for Eclipse. You can create, modify, and build Nios II programs with commands typed at a command line or embedded in a script.

[Table 4-13](#) summarizes the command-line utilities and scripts included in the Nios II Software Build Tools. You can call these utilities and scripts on the command line or from the scripting language of your choice (such as **perl** or **bash**).



**Table 4-13.** Nios II Software Build Tools Utilities and Scripts

Command	Summary	Utility	Script
<b>nios2-app-generate-makefile</b>	Creates an application makefile	✓	
<b>nios2-lib-generate-makefile</b>	Creates a user library makefile	✓	
<b>nios2-app-update-makefile</b>	Modifies an existing application makefile	✓	
<b>nios2-lib-update-makefile</b>	Modifies an existing user library makefile	✓	
<b>nios2-bsp-create-settings</b>	Creates a BSP settings file	✓	
<b>nios2-bsp-update-settings</b>	Updates the contents of a BSP settings file	✓	
<b>nios2-bsp-query-settings</b>	Queries the contents of a BSP settings file	✓	
<b>nios2-bsp-generate-files</b>	Generates all files for a given BSP settings file	✓	
<b>nios2-bsp</b>	Creates or updates a BSP		✓
<b>create-this-app</b>	Creates an example application project		✓
<b>create-this-bsp</b>	Creates an example BSP project		✓
<b>nios2-c2h-generate-makefile</b>	Creates an application makefile fragment for the Nios II C2H Compiler. (1)		✓

**Note to Table 4-13:**

- (1) The **nios2-c2h-generate-makefile** script is available to support pre-existing command-line C2H projects. Create new C2H projects using the Nios II IDE.

The Nios II Software Build Tools utilities reside in the *<Nios II EDS install path>/sdk2/bin* directory.



For further information about the Nios II Software Build Tools, refer to the *Getting Started from the Command Line* chapter of the *Nios II Software Developer's Handbook*.

## File Format Conversion Tools

File format conversion is sometimes necessary when passing data from one utility to another. Table 4-14 shows the Altera-provided utilities for converting file formats.



These tools are also used with the Nios II IDE.

**Table 4-14.** File Conversion Utilities

Utility	Description
<b>bin2flash</b>	Converts binary files to a Nios II Flash Programmer File (.flash) for programming to flash memory.
<b>elf2dat</b>	Converts a .elf file to a .dat file format appropriate for Verilog HDL hardware simulators.
<b>elf2flash</b>	Converts a .elf file to a .flash file for programming to flash memory.
<b>elf2hex</b>	Converts a .elf file to a Hexadecimal (Intel-format) File (.hex).
<b>elf2mem</b>	Generates the memory contents for the memory devices in a specific Nios II system.
<b>elf2mif</b>	Converts a .elf file to a Quartus® II Memory Initialization File (.mif).
<b>flash2dat</b>	Converts a .flash file to the .dat file format appropriate for Verilog HDL hardware simulators.
<b>sof2flash</b>	Converts an SRAM Object File (.sof) to a .flash file.

The file format conversion tools are in the *<Nios II EDS install path>/bin/* directory.

### Other Command-Line Tools

Table 4-15 shows other Altera-provided command-line tools for developing Nios II programs.



These tools are also used with the Nios II IDE.

**Table 4-15.** Altera Command-Line Tools

Tool	Description
<b>nios2-download</b>	Downloads code to a target processor for debugging or running.
<b>nios2-flash-programmer-generate</b>	Allows multiple files to be converted to <b>.flash</b> files, and optionally programs each file to the specified location on a flash device.
<b>nios2-flash-programmer</b>	Programs data to flash memory on the target board.
<b>nios2-gdb-server</b>	Translates GNU debugger (GDB) remote serial protocol packets over Transmission Control Protocol (TCP) to JTAG transactions with a target Nios II processor.
<b>nios2-terminal</b>	Performs terminal I/O with a JTAG UART in a Nios II system
<b>validate_zip</b>	Verifies if a specified zip file is compatible with Altera's read-only zip file system.
<b>nios2-debug</b>	Downloads a program to a Nios II processor and launches the Insight debugger.
<b>nios2-configure-sof</b>	Configures an Altera configurable part. If no explicit <b>.sof</b> file is specified, it tries to determine the correct file to use.
<b>jtagconfig</b>	Allows you configure the JTAG server on the host machine. It can also detect a JTAG chain and set up the download hardware configuration.

The command-line tools described in this section are in the *<Nios II EDS install path>/bin/* directory.

## Restrictions

The Nios II Software Build Tools have the following restrictions:

- The Nios II Software Build Tools are only supported by SOPC Builder release 7.1 or later. The Nios II Software Build Tools require a SOPC Information File (**.sopcinfo**) for the system description.
  - If you have a legacy hardware design based on an SOPC Builder system file (**.ptf**), SOPC Builder can convert your **.ptf** to a **.sopcinfo** file.
  - If your hardware design was generated with SOPB Builder release 7.1 or 7.2, regenerate it with SOPC Builder release 8.0 or later before creating a BSP.
- The Nios II Software Build Tools support BSPs incorporating the Altera HAL and Micrium MicroC/OS-II only.

## Referenced Documents

This chapter references the following documents:

- *Overview* chapter of the *Nios II Software Developer's Handbook*
- *Getting Started with the Graphical User Interface* chapter of the *Nios II Software Developer's Handbook*
- *Getting Started from the Command Line* chapter of the *Nios II Software Developer's Handbook*
- *Hardware Abstraction Layer* section of the *Nios II Software Developer's Handbook*
- *Developing Programs Using the Hardware Abstraction Layer* 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*
- *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*
- *Appendix A. Using the Nios II Integrated Development Environment* in the *Nios II Software Developer's Handbook*

## Document Revision History

Table 4-16 shows the revision history for this document.

**Table 4-16.** Document Revision History (Part 1 of 2)

Date & Document Version	Changes Made	Summary of Changes
November 2009 v9.1.0	<ul style="list-style-type: none"> <li>■ Chapter repurposed and retitled to cover Nios II Software Build Tools functionality applicable to both command line and Eclipse</li> <li>■ Describe the Nios II Flash Programmer</li> </ul>	<ul style="list-style-type: none"> <li>■ Introduction of the Nios II Software Build Tools for Eclipse</li> </ul>
March 2009 v9.0.0	<ul style="list-style-type: none"> <li>■ Moved information about Tcl-based device drivers and software packages, formerly in this chapter, to <i>Developing device Drivers for the Hardware Abstraction Layer</i>.</li> <li>■ Described how to work with compiler optimization and debugger settings.</li> <li>■ Described newlib recompilation.</li> <li>■ Corrected minor typographical errors.</li> </ul>	<ul style="list-style-type: none"> <li>■ Compiler optimization and debugger settings</li> <li>■ newlib recompilation</li> </ul>

**Table 4-16.** Document Revision History (Part 2 of 2)

<b>Date &amp; Document Version</b>	<b>Changes Made</b>	<b>Summary of Changes</b>
May 2008 v8.0.0	<ul style="list-style-type: none"> <li>■ Add instructions for writing instruction-related exception handler</li> <li>■ Example designs removed from list</li> </ul>	<ul style="list-style-type: none"> <li>■ Advanced exceptions added to Nios II core</li> <li>■ Instruction-related exception handling added to HAL</li> <li>■ Example designs removed from EDS</li> </ul>
October 2007 v7.2.0	Initial release. Material moved here from former <i>Nios II Software Build Tools</i> chapter.	—

This section describes the Nios® II hardware abstraction layer (HAL). It includes the following chapters:

- [Chapter 5, Overview of the Hardware Abstraction Layer](#)
- [Chapter 6, Developing Programs Using the Hardware Abstraction Layer](#)
- [Chapter 7, Developing Device Drivers for the Hardware Abstraction Layer](#)



## Introduction

This chapter introduces the hardware abstraction layer (HAL) for the Nios® II processor. This chapter contains the following sections:

- “Getting Started” on page 5–1
- “HAL Architecture” on page 5–2
- “Supported Peripherals” on page 5–4

The HAL is a lightweight runtime environment that provides a simple device driver interface for programs to connect to the underlying hardware. The HAL application program interface (API) is integrated with the ANSI C standard library. The HAL API allows you to access devices and files using familiar C library functions, such as `printf()`, `fopen()`, `fwrite()`, etc.

The HAL serves as a device driver package for Nios II processor systems, providing a consistent interface to the peripherals in your system. Tight integration between SOPC Builder and the Nios II software development tools automates the construction of a HAL instance for your hardware. After SOPC Builder generates a hardware system, the Nios II Software Build Tools can generate a custom HAL board support package (BSP) to match the hardware configuration. Changes in the hardware configuration automatically propagate to the HAL device driver configuration, preventing changes in the underlying hardware from creating bugs.

HAL device driver abstraction provides a clear distinction between application and device driver software. This driver abstraction promotes reusable application code that is resistant to changes in the underlying hardware. In addition, the HAL standard makes it straightforward to write drivers for new hardware peripherals that are consistent with existing peripheral drivers.

## Getting Started

The easiest way to get started using the HAL is to create a software project. In the process of creating a new project, you also create a HAL BSP. You need not create or copy HAL files, and you need not edit any of the HAL source code. The Nios II Software Build Tools generate the HAL BSP for you.



For an exercise in creating a simple Nios II HAL software project, refer to “Getting Started” in the *Getting Started with the Graphical User Interface* chapter of the *Nios II Software Developer’s Handbook*.

In the Nios II Software Build Tools Software Build Tools command line, you can create an example BSP based on the HAL using one of the **create-this-bsp** scripts supplied with the Nios II Embedded Design Suite.

You must base the HAL on a specific SOPC Builder system. An SOPC Builder system is a Nios II processor core integrated with peripherals and memory (which is generated by SOPC Builder). If you do not have a custom SOPC Builder system, you can base your project on an Altera-provided example hardware system. In fact, you can first start developing projects targeting an Altera® Nios development board, and later re-target the project to a custom board. You can easily change the target SOPC Builder system later.



For information about creating a new project with the Nios II Software Build Tools, refer to the *Getting Started with the Graphical User Interface* chapter of the *Nios II Software Developer's Handbook*, or to the *Getting Started from the Command Line* chapter of the *Nios II Software Developer's Handbook*.

## HAL Architecture

This section describes the fundamental elements of the HAL architecture.

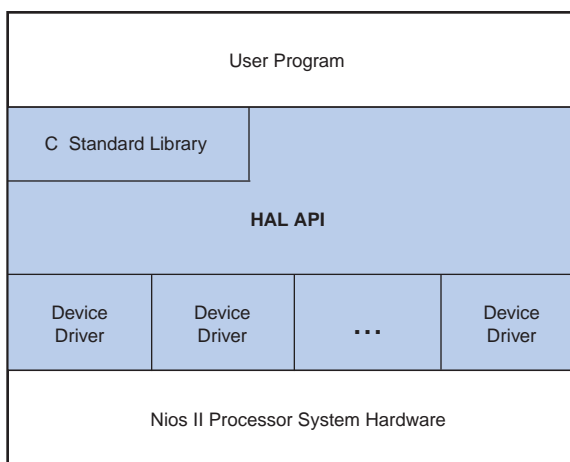
### Services

The HAL provides the following services:

- Integration with the newlib ANSI C standard library—Provides the familiar C standard library functions
- Device drivers—Provides access to each device in the system
- The HAL API—Provides a consistent, standard interface to HAL services, such as device access, interrupt handling, and alarm facilities
- System initialization—Performs initialization tasks for the processor and the runtime environment before `main()`
- Device initialization—Instantiates and initializes each device in the system before `main()` runs

Figure 5–1 shows the layers of a HAL-based system, from the hardware level up to a user program.

**Figure 5–1.** The Layers of a HAL-Based System





## Applications versus Drivers

Application developers are responsible for writing the system's `main()` routine, among other routines. Applications interact with system resources either through the C standard library, or through the HAL API. Device driver developers are responsible for making device resources available to application developers. Device drivers communicate directly with hardware through low-level hardware access macros.



For further details about the HAL, refer to the following chapters:

- The *Developing Programs Using the Hardware Abstraction Layer* chapter of the *Nios II Software Developer's Handbook* describes how to take advantage of the HAL to write programs without considering the underlying hardware.
- The *Developing Device Drivers for the Hardware Abstraction Layer* chapter of the *Nios II Software Developer's Handbook* describes how to communicate directly with hardware and how to make hardware resources available with the HAL API.

## Generic Device Models

The HAL provides generic device models for classes of peripherals found in embedded systems, such as timers, Ethernet MAC/PHY chips, and I/O peripherals that transmit character data. The generic device models are at the core of the HAL's power. The generic device models allow you to write programs using a consistent API, regardless of the underlying hardware.

### Device Model Classes

The HAL provides models for the following classes of devices:

- Character-mode devices—Hardware peripherals that send and/or receive characters serially, such as a UART.
- Timer devices—Hardware peripherals that count clock ticks and can generate periodic interrupt requests.
- File subsystems—A mechanism for accessing files stored in physical device(s). Depending on the internal implementation, the file subsystem driver might access the underlying device(s) directly or use a separate device driver. For example, you can write a flash file subsystem driver that accesses flash using the HAL API for flash memory devices.
- Ethernet devices—Devices that provide access to an Ethernet connection for a networking stack such as the Altera-provided NicheStack® TCP/IP Stack - Nios II Edition. You need a networking stack to use an ethernet device.
- Direct memory access (DMA) devices—Peripherals that perform bulk data transactions from a data source to a destination. Sources and destinations can be memory or another device, such as an Ethernet connection.
- Flash memory devices—Nonvolatile memory devices that use a special programming protocol to store data.

### Benefits to Application Developers

The HAL defines a set of functions that you use to initialize and access each class of device. The API is consistent, regardless of the underlying implementation of the device hardware. For example, to access character-mode devices and file subsystems, you can use the C standard library functions, such as `printf()` and `fopen()`. For application developers, you need not write low-level routines just to establish basic communication with the hardware for these classes of peripherals.

### Benefits to Device Driver Developers

Each device model defines a set of driver functions necessary to manipulate the particular class of device. If you are writing drivers for a new peripheral, you need only provide this set of driver functions. As a result, your driver development task is predefined and well documented. In addition, you can use existing HAL functions and applications to access the device, which saves software development effort. The HAL calls driver functions to access hardware. Application programmers call the ANSI C or HAL API to access hardware, rather than calling your driver routines directly. Therefore, the usage of your driver is already documented as part of the HAL API.

## C Standard Library—Newlib

The HAL integrates the ANSI C standard library in its runtime environment. The HAL uses newlib, an open-source implementation of the C standard library. newlib is a C library for use on embedded systems, making it a perfect match for the HAL and the Nios II processor. newlib licensing does not require you to release your source code or pay royalties for projects based on newlib.

The ANSI C standard library is well documented. Perhaps the most well-known reference is *The C Programming Language* by B. Kernighan and D. Ritchie, published by Prentice Hall and available in over 20 languages. Redhat also provides online documentation for newlib at <http://sources.redhat.com/newlib>.

## Supported Hardware

This section summarizes Nios II HAL support for Nios II hardware.

### Nios II Processor Core Support

The Nios II HAL supports all available Nios II processor core implementations.

### Supported Peripherals

Altera provides many peripherals for use in Nios II processor systems. Most Altera peripherals provide HAL device drivers that allow you to access the hardware with the HAL API. The following Altera peripherals provide full HAL support:

- Character mode devices
  - UART core
  - JTAG UART core
  - LCD 16207 display controller

- Flash memory devices
  - Common flash interface compliant flash chips
  - Altera's erasable programmable configurable serial (EPCS) serial configuration device controller
- File subsystems
  - Altera host based file system
  - Altera read-only zip file system
- Timer devices
  - Timer core
- DMA devices
  - DMA controller core
  - Scatter-gather DMA controller core
- Ethernet devices
  - Triple Speed Ethernet MegaCore® function
  - LAN91C111 Ethernet MAC/PHY Controller

The LAN91C111 and Triple Speed Ethernet components require the MicroC/OS-II runtime environment.



For more information, refer to the *Ethernet and the NicheStack TCP/IP Stack - Nios II Edition* chapter of the *Nios II Software Developer's Handbook*. Third-party vendors offer additional peripherals not listed here. For a list of other peripherals available for the Nios II processor, visit the [Embedded Software](#) page of the Altera website.

All peripherals (both from Altera and third party vendors) must provide a header file that defines the peripheral's low-level interface to hardware. Therefore, all peripherals support the HAL to some extent. However, some peripherals might not provide device drivers. If drivers are not available, use only the definitions provided in the header files to access the hardware. Do not use unnamed constants, such as hard-coded addresses, to access a peripheral.

Inevitably, certain peripherals have hardware-specific features with usage requirements that do not map well to a general-purpose API. The HAL handles hardware-specific requirements by providing the UNIX-style `ioctl()` function. Because the hardware features depend on the peripheral, the `ioctl()` options are documented in the description for each peripheral.

Some peripherals provide dedicated accessor functions that are not based on the HAL generic device models. For example, Altera provides a general-purpose parallel I/O (PIO) core for use with the Nios II processor system. The PIO peripheral does not fit in any class of generic device models provided by the HAL, and so it provides a header file and a few dedicated accessor functions only.



For complete details regarding software support for a peripheral, refer to the peripheral's description. For further details about Altera-provided peripherals, refer to *Volume 5: Embedded Peripherals* of the *Quartus® II Handbook*.

## MPU Support

The HAL does not include explicit support for the optional memory protection unit (MPU) hardware. However, it does support an advanced exception handling system that can handle Nios II MPU exceptions.



For details about handling MPU and other advanced exceptions, refer to the *Exception Handling* chapter of the *Nios II Software Developer's Handbook*. For details about the MPU hardware implementation, refer to the *Programming Model* chapter of the *Nios II Processor Reference Handbook*.

## MMU Support

The HAL does not support the optional memory management unit (MMU) hardware. To use the MMU, you need to implement a full-featured operating system.

For details about the Nios II MMU, refer to the *Programming Model* chapter of the *Nios II Processor Reference Handbook*.

## Referenced Documents

This chapter references the following documents:

- *Getting Started with the Graphical User Interface* chapter of the *Nios II Software Developer's Handbook*
- *Getting Started from the Command Line* chapter of the *Nios II Software Developer's Handbook*
- *Developing Programs Using the Hardware Abstraction Layer* 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*
- *Ethernet and the NicheStack TCP/IP Stack - Nios II Edition* chapter of the *Nios II Software Developer's Handbook*
- *Programming Model* chapter of the *Nios II Processor Reference Handbook*
- *Volume 5: Embedded Peripherals* of the *Quartus II Handbook*
- The *Embedded Software* page of the Altera website

## Document Revision History

Table 5–1 shows the revision history for this document.

**Table 5–1.** Document Revision History

Date & Document Version	Changes Made	Summary of Changes
November 2009 v9.1.0	No change from previous release.	
March 2009 v9.0.0	<ul style="list-style-type: none"> <li>■ Reorganized and updated information and terminology to clarify role of Nios II Software Build Tools.</li> <li>■ Corrected minor typographical errors.</li> </ul>	
May 2008 v8.0.0	No change from previous release.	
October 2007 v7.2.0	No change from previous release.	
May 2007 v7.1.0	<ul style="list-style-type: none"> <li>■ Scatter-gather DMA core</li> <li>■ Triple-speed Ethernet MAC</li> <li>■ Refer to HAL generation with Nios II Software Build Tools.</li> <li>■ Added table of contents to “Introduction” section.</li> <li>■ Added Referenced Documents section.</li> </ul>	<ul style="list-style-type: none"> <li>■ Scatter-gather DMA core</li> <li>■ Triple-speed Ethernet MAC</li> <li>■ Nios II Software Build Tools</li> </ul>
March 2007 v7.0.0	No change from previous release.	
November 2006 v6.1.0	NicheStack TCP/IP Stack - Nios II Edition	
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.	
May 2004 v1.0	Initial Release.	



## Introduction

This chapter discusses how to develop programs for the Nios® II processor based on the Altera® hardware abstraction layer (HAL). This chapter contains the following sections:

- “The Nios II Project Structure” on page 6–2
- “The system.h System Description File” on page 6–4
- “Data Widths and the HAL Type Definitions” on page 6–5
- “UNIX-Style Interface” on page 6–5
- “File System” on page 6–6
- “Using Character-Mode Devices” on page 6–8
- “Using File Subsystems” on page 6–15
- “Using Timer Devices” on page 6–16
- “Using Flash Devices” on page 6–19
- “Using DMA Devices” on page 6–25
- “Using Interrupt Controllers” on page 6–30
- “Reducing Code Footprint” on page 6–30
- “Boot Sequence and Entry Point” on page 6–37
- “Memory Usage” on page 6–39
- “Working with HAL Source Files” on page 6–44

The application program interface (API) for HAL-based systems is readily accessible to software developers who are new to the Nios II processor. Programs based on the HAL use the ANSI C standard library functions and runtime environment, and access hardware resources with the HAL API’s generic device models. The HAL API largely conforms to the familiar ANSI C standard library functions, though the ANSI C standard library is separate from the HAL. The close integration of the ANSI C standard library and the HAL makes it possible to develop useful programs that never call the HAL functions directly. For example, you can manipulate character mode devices and files using the ANSI C standard library I/O functions, such as `printf()` and `scanf()`.



This document does not cover the ANSI C standard library. An excellent reference is *The C Programming Language, Second Edition*, by Brian Kernighan and Dennis M. Ritchie (Prentice-Hall).

## Nios II Development Flows

The Nios II Embedded Design Suite (EDS) provides two distinct development flows for creating Nios II programs. You can use the Nios II Software Build Tools, or work in the Nios II integrated development environment (IDE). These two approaches use the HAL in the same way.



In most cases, you should create new projects using either the Nios II Software Build Tools for Eclipse™ or the Software Build Tools command line. The IDE will be discontinued in a future release. IDE support is for the following situations:

- Working with pre-existing Nios II IDE software projects
- Creating new projects for the Nios II C2H compiler
- Debugging with the FS2 console

## HAL BSP Settings

Every Nios II board support package (BSP) has settings that determine the BSP's characteristics. For example, HAL BSPs have settings to identify the hardware components associated with standard devices such as `stdout`. Defining and manipulating BSP settings is an important part of Nios II project creation. You manipulate BSP settings with the Nios II BSP Editor, with command-line options, or with Tcl scripts.



For details about how to control BSP settings, refer to one or more of the following documents:

- For the Nios II Software Build Tools for Eclipse, refer to the *Getting Started with the Graphical User Interface* chapter of the *Nios II Software Developer's Handbook*.
- For the Nios II Software Build Tools command line, refer to the *Nios II Software Build Tools* chapter of the *Nios II Software Developer's Handbook*.



For detailed descriptions of available BSP settings, refer to the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*.

Many HAL settings are reflected in the **system.h** file, which provides a helpful reference for details about your BSP. For information about **system.h**, refer to “*The system.h System Description File*” on page 6–4.



Do not edit **system.h**. The Nios II EDS provides tools to manipulate system settings.

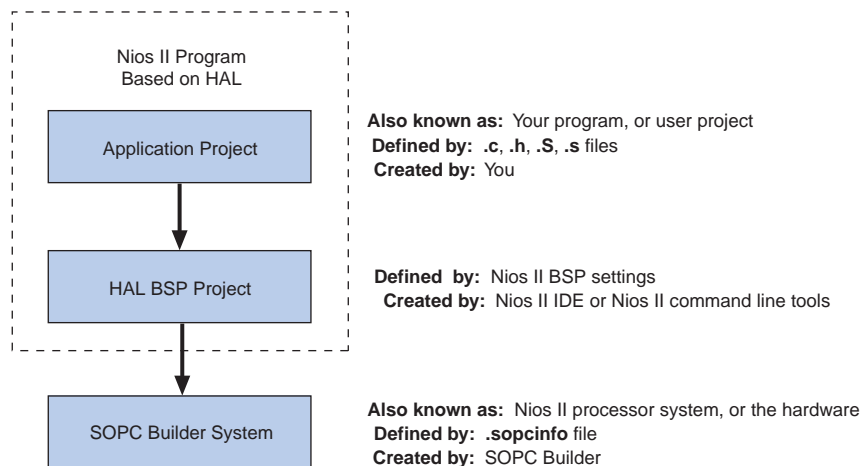
## The Nios II Project Structure

The creation and management of software projects based on the HAL is integrated tightly with the Nios II Software Build Tools. This section discusses the Nios II projects as a basis for understanding the HAL.

Figure 6–1 shows the blocks of a Nios II program with emphasis on how the HAL BSP fits in. The label for each block describes what or who generated that block, and an arrow points to each block's dependency.



**Figure 6–1.** The Nios II HAL Project Structure



Every HAL-based Nios II program consists of two Nios II projects, as shown in [Figure 6–1](#). Your application-specific code is contained in one project (the user application project), and it depends on a separate BSP project (the HAL BSP).

The application project contains all the code you develop. The executable image for your program ultimately results from building both projects.

With the Nios II Software Build Tools for Eclipse, the tools create the HAL BSP project when you create your application project. In the Nios II Software Build Tools command line flow, you create the BSP using **nios2-bsp** or a related tool.

The HAL BSP project contains all information needed to interface your program to the hardware. The HAL drivers relevant to your SOPC Builder system are incorporated in the BSP project.

The BSP project depends on the SOPC Builder system, defined by a SOPC Information File (**.sopcinfo**). The Nios II Software Build Tools can keep your BSP up-to-date with the SOPC Builder system. This project dependency structure isolates your program from changes to the underlying hardware, and you can develop and debug code without concern about whether your program matches the target hardware.

You can use the Nios II Software Build Tools to update your BSP to match updated hardware. You control whether and when these updates occur.



For details about how the Software Build Tools keep your BSP up-to-date with your hardware system, refer to “Revising Your BSP” in the [Nios II Software Build Tools](#) chapter of the *Nios II Software Developer’s Handbook*.

In summary, when your program is based on a HAL BSP, you can always keep it synchronized with the target hardware with a few simple Software Build Tools commands.

## The system.h System Description File

The **system.h** file provides a complete software description of the Nios II system hardware. Not all information in **system.h** is useful to you as a programmer, and it is rarely necessary to include it explicitly in your C source files. Nonetheless, **system.h** holds the answer to the question, “What hardware is present in this system?”

The **system.h** file describes each peripheral in the system and provides the following details:

- The hardware configuration of the peripheral
- The base address
- Interrupt request (IRQ) information (if any)
- A symbolic name for the peripheral

The Nios II Software Build Tools generate the **system.h** file for HAL BSP projects. The contents of **system.h** depend on both the hardware configuration and the HAL BSP properties.



Do not edit **system.h**. The Software Build Tools provide facilities to manipulate system settings.

For details about how to control BSP settings, refer to “[HAL BSP Settings](#)” on [page 6-2](#).

The code in [Example 6-1](#) from a **system.h** file shows some of the hardware configuration options this file defines.

### Example 6-1. Excerpts from a system.h File

---

```

/*
 * sys_clk_timer configuration
 *
 */

#define SYS_CLK_TIMER_NAME "/dev/sys_clk_timer"
#define SYS_CLK_TIMER_TYPE "altera_avalon_timer"
#define SYS_CLK_TIMER_BASE 0x00920800
#define SYS_CLK_TIMER_IRQ 0
#define SYS_CLK_TIMER_ALWAYS_RUN 0
#define SYS_CLK_TIMER_FIXED_PERIOD 0

/*
 * jtag_uart configuration
 *
 */

#define JTAG_UART_NAME "/dev/jtag_uart"
#define JTAG_UART_TYPE "altera_avalon_jtag_uart"
#define JTAG_UART_BASE 0x00920820
#define JTAG_UART_IRQ 1

```

---

## Data Widths and the HAL Type Definitions

For embedded processors such as the Nios II processor, it is often important to know the exact width and precision of data. Because the ANSI C data types do not explicitly define data width, the HAL uses a set of standard type definitions instead. The ANSI C types are supported, but their data widths are dependent on the compiler's convention.

The header file **alt\_types.h** defines the HAL type definitions; [Table 6-1](#) shows the HAL type definitions.

**Table 6-1.** The HAL Type Definitions

Type	Meaning
alt_8	Signed 8-bit integer.
alt_u8	Unsigned 8-bit integer.
alt_16	Signed 16-bit integer.
alt_u16	Unsigned 16-bit integer.
alt_32	Signed 32-bit integer.
alt_u32	Unsigned 32-bit integer.
alt_64	Signed 64-bit integer.
alt_u64	Unsigned 64-bit integer.

[Table 6-2](#) shows the data widths that the Altera-provided GNU toolchain uses.

**Table 6-2.** GNU Toolchain Data Widths

Type	Meaning
char	8 bits.
short	16 bits.
long	32 bits.
int	32 bits.

## UNIX-Style Interface

The HAL API provides a number of UNIX-style functions. The UNIX-style functions provide a familiar development environment for new Nios II programmers, and can ease the task of porting existing code to run in the HAL environment. The HAL uses these functions primarily to provide the system interface for the ANSI C standard library. For example, the functions perform device access required by the C library functions defined in **stdio.h**.

The following list contains all of the available UNIX-style functions:

- `_exit()`
- `close()`
- `fstat()`
- `getpid()`
- `gettimeofday()`

- `ioctl()`
- `isatty()`
- `kill()`
- `lseek()`
- `open()`
- `read()`
- `sbrk()`
- `settimeofday()`
- `stat()`
- `usleep()`
- `wait()`
- `write()`

The most commonly used functions are those that relate to file I/O. Refer to “[File System](#)” on page 6-6.



For details about the use of these functions, refer to the [HAL API Reference](#) chapter of the *Nios II Software Developer's Handbook*.

## File System

The HAL provides infrastructure for UNIX-style file access. You can use this infrastructure to build a file system on any storage devices available in your hardware.




For an example, refer to the [Read-Only Zip File System](#) chapter of the *Nios II Software Developer's Handbook*.

You can access files in a HAL-based file system by using either the C standard library file I/O functions in the newlib C library (for example `fopen()`, `fclose()`, and `fread()`), or using the UNIX-style file I/O provided by the HAL.

The HAL provides the following UNIX-style functions for file manipulation:

- `close()`
- `fstat()`
- `ioctl()`
- `isatty()`
- `lseek()`
- `open()`
- `read()`
- `stat()`
- `write()`

 For more information about these functions, refer to the *HAL API Reference* chapter of the *Nios II Software Developer's Handbook*.

The HAL registers a file subsystem as a mount point in the global HAL file system. Attempts to access files below that mount point are directed to the file subsystem. For example, if a read-only zip file subsystem (**zipfs**) is mounted as **/mount/zipfs0**, the **zipfs** file subsystem handles calls to `fopen ( )` for **/mount/zipfs0/myfile**.

There is no concept of a current directory. Software must access all files using absolute paths.

The HAL file infrastructure also allows you to manipulate character mode devices with UNIX-style path names. The HAL registers character mode devices as nodes in the HAL file system. By convention, **system.h** defines the name of a device node as the prefix **/dev/** plus the name assigned to the hardware component in SOPC builder. For example, a UART peripheral **uart1** in SOPC builder is **/dev/uart1** in **system.h**.

The code in [Example 6-2](#) reads characters from a read-only zip file subsystem **rozipfs** that is registered as a node in the HAL file system. The standard header files `stdio.h`, `stddef.h`, and `stdlib.h` are installed with the HAL.

---

**Example 6-2.** Reading Characters from a File Subsystem

---

```
#include <stdio.h>
#include <stddef.h>
#include <stdlib.h>

#define BUF_SIZE (10)

int main(void)
{
    FILE* fp;
    char buffer[BUF_SIZE];


    fp = fopen ("/mount/rozipfs/test", "r"); if (fp == NULL)
    {
        printf ("Cannot open file.\n");
        exit (1);
    }

    fread (buffer, BUF_SIZE, 1, fp);

    fclose (fp);

    return 0;
}
```

---

 For more information about the use of these functions, refer to the newlib C library documentation installed with the Nios II EDS. On the Windows Start menu, click **Programs > Altera > Nios II > Nios II Documentation**.

## Using Character-Mode Devices

A character-mode device is a hardware peripheral that sends and/or receives characters serially. A common example is the UART. Character mode devices are registered as nodes in the HAL file system. In general, a program associates a file descriptor to a device's name, and then writes and reads characters to or from the file using the ANSI C file operations defined in **file.h**. The HAL also supports the concept of standard input, standard output, and standard error, allowing programs to call the **stdio.h** I/O functions.

### Standard Input, Standard Output and Standard Error

Using standard input (**stdin**), standard output (**stdout**), and standard error (**stderr**) is the easiest way to implement simple console I/O. The HAL manages **stdin**, **stdout**, and **stderr** behind the scenes, which allows you to send and receive characters through these channels without explicitly managing file descriptors. For example, the HAL directs the output of **printf()** to standard out, and **perror()** to standard error. You associate each channel to a specific hardware device by manipulating BSP settings.

The code in [Example 6-3](#) shows the classic Hello World program. This program sends characters to whatever device is associated with **stdout** when the program is compiled.

---

**Example 6-3.** Hello World

---

```
#include <stdio.h>
int main ()
{
    printf ("Hello world!");
    return 0;
}
```

---

When using the UNIX-style API, you can use the file descriptors **stdin**, **stdout**, and **stderr**, defined in **unistd.h**, to access, respectively, the standard in, standard out, and standard error character I/O streams. **unistd.h** is installed with the Nios II EDS as part of the newlib C library package.

### General Access to Character Mode Devices

Accessing a character-mode device other than **stdin**, **stdout**, or **stderr** is as easy as opening and writing to a file. The code in [Example 6-4](#) writes a message to a UART called **uart1**.

---

**Example 6-4. Writing Characters to a UART**

---

```
#include <stdio.h>
#include <string.h>

int main (void)
{
    char* msg = "hello world";
    FILE* fp;

    fp = fopen ("/dev/uart1", "w");
    if (fp!=NULL)
    {
        fprintf(fp, "%s",msg);
        fclose (fp);
    }
    return 0;
}
```

---

## C++ Streams

HAL-based systems can use the C++ streams API for manipulating files from C++.

## /dev/null

All systems include the device **/dev/null**. Writing to **/dev/null** has no effect, and all data is discarded. **/dev/null** is used for safe I/O redirection during system startup. This device can also be useful for applications that wish to sink unwanted data.

This device is purely a software construct. It does not relate to any physical hardware device in the system.

## Lightweight Character-Mode I/O

The HAL offers several methods of reducing the code footprint of character-mode device drivers. For details, refer to [“Reducing Code Footprint” on page 6-30](#).

## Altera Logging Functions

The Altera logging functions provide a separate channel for sending logging and debugging information to a character-mode device, supplementing `stdout` and `stderr`. The Altera logging information can be printed in response to several conditions. Altera logging can be enabled and disabled independently of any normal `stdio` output, making it a powerful debugging tool.

When Altera logging is enabled, your software can print extra messages to a specified port with HAL function calls. The logging port, specified in the BSP, can be a UART or a JTAG UART device. In its default configuration, Altera logging prints out boot messages, which trace each step of the boot process.



Avoid setting the Altera logging device to the device used for `stdout` or `stderr`. If Altera logging output is sent to `stdout` or `stderr`, the logging output might appear interleaved with the `stdout` or `stderr` output

Several logging options are available, controlled by C preprocessor symbols. You can also choose to add custom logging messages.



Altera logging changes system behavior. The logging implementation is designed to be as simple as possible, loading characters directly to the transmit register. It can have a negative impact on software performance.

Altera logging functions are conditionally compiled. When logging is disabled, it has no impact on code footprint or performance.



The Altera reduced device drivers do not support Altera logging.

### Enabling Altera Logging

The Nios II Software Build Tools have a setting to enable Altera logging. The setting is called **hal.log\_port**. It is similar to **hal.stdout**, **hal.stdin**, and **hal.stderr**. To enable Altera logging, you set **hal.log\_port** to a JTAG UART or a UART device. The setting allows the HAL to send log messages to the specified device when a logging macro is invoked.

When Altera logging is enabled, the Nios II Software Build Tools define **ALT\_LOG\_ENABLE** in **public.mk** to enable log messages. The build tools also set the **ALT\_LOG\_PORT\_TYPE** and **ALT\_LOG\_PORT\_BASE** values in **system.h** to point to the specified device.

When Altera logging is enabled without special options, the HAL prints out boot messages to the selected port. For typical software that uses the standard **alt\_main.c** (such as the Hello World software example), the messages appear as in [Example 6-5](#).

#### Example 6-5. Default Boot Logging Output

```
[crt0.S] Inst & Data Cache Initialized.
[crt0.S] Setting up stack and global pointers.
[crt0.S] Clearing BSS
[crt0.S] Calling alt_main.
[alt_main.c] Entering alt_main, calling alt_irq_init.
[alt_main.c] Done alt_irq_init, calling alt_os_init.
[alt_main.c] Done OS Init, calling alt_sem_create.
[alt_main.c] Calling alt_sys_init.
[alt_main.c] Done alt_sys_init. Redirecting IO.
[alt_main.c] Calling C++ constructors.
[alt_main.c] Calling main.
[alt_exit.c] Entering _exit() function.
[alt_exit.c] Exit code from main was 0.
[alt_exit.c] Calling ALT_OS_STOP().
[alt_exit.c] Calling ALT_SIM_HALT().
[alt_exit.c] Spinning forever.
```



A write operation to the Altera logging device stalls in **ALT\_LOG\_PRINTF( )** until the characters are read from the Altera logging device's output buffer. To ensure that the Nios II application completes initialization, run the **nios2-terminal** command from the Nios II Command Shell to accept the Altera logging output.



## Extra Logging Options

In addition to the default boot messages, logging options are incorporated in Altera logging. Each option is controlled by a C preprocessor symbol. The details of each option are outlined in [Table 6-3](#).

**Table 6-3.** Altera Logging Options (Part 1 of 2)

Name	Description	
System clock log	Purpose	Prints out a message from the system clock interrupt handler at a specified interval. This indicates that the system is still running. The default interval is every 1 second.
	Preprocessor symbol	ALT_LOG_SYS_CLK_ON_FLAG_SETTING
	Modifiers	<p>The system clock log has two modifiers, providing two different ways to specify the logging interval.</p> <ul style="list-style-type: none"> <li>■ ALT_LOG_SYS_CLK_INTERVAL—Specifies the logging interval in system clock ticks. The default is <i>&lt;clock ticks per second&gt;</i>, that is, one second.</li> <li>■ ALT_LOG_SYS_CLK_INTERVAL_MULTIPLIER—Specifies the logging interval in seconds. The default is 1. When you modify ALT_LOG_SYS_CLK_INTERVAL_MULTIPLIER, ALT_LOG_SYS_CLK_INTERVAL is recalculated.</li> </ul>
	Sample Output	System Clock On 0 System Clock On 1
Write echo	Purpose	Every time <code>alt_write()</code> is called (normally, whenever characters are sent to <code>stdout</code> ), the first <i>&lt;n&gt;</i> characters are echoed to a logging message. The message starts with the string "Write Echo:". <i>&lt;n&gt;</i> is specified with ALT_LOG_WRITE_ECHO_LEN. The default is 15 characters.
	Preprocessor symbol	ALT_LOG_WRITE_ON_FLAG_SETTING
	Modifiers	ALT_LOG_WRITE_ECHO_LEN—Number of characters to echo. Default is 15.
	Sample Output	Write Echo: Hello from Nio
JTAG startup log	Purpose	<p>At JTAG UART driver initialization, print out a line with the number of characters in the software transmit buffer followed by the JTAG UART control register contents. The number of characters, prefaced by the string "SW CirBuf", might be negative, because it is computed as (<i>&lt;tail_pointer&gt;</i> – <i>&lt;head_pointer&gt;</i>) on a circular buffer.</p> <p>For more information about the JTAG UART control register fields, refer to the <a href="#">Off-Chip Interface Peripherals</a> section in <i>Volume 5: Embedded Peripherals of the Quartus® II Handbook</i>.</p>
	Preprocessor symbol	ALT_LOG_JTAG_UART_STARTUP_INFO_ON_FLAG_SETTING
	Modifiers	None
	Sample Output	JTAG Startup Info: SW CirBuf = 0, HW FIFO wspace=64 AC=0 WI=0 RI=0 WE=0 RE=1

**Table 6-3.** Altera Logging Options (Part 2 of 2)

Name	Description	
JTAG interval log	Purpose	Creates an alarm object to print out the same JTAG UART information as the JTAG startup log, but at a repeated interval. Default interval is 0.1 second, or 10 messages a second.
	Preprocessor symbol	ALT_LOG_JTAG_UART_ALARM_ON_FLAG_SETTING
	Modifiers	The JTAG interval log has two modifiers, providing two different ways to specify the logging interval. <ul style="list-style-type: none"> <li>■ ALT_LOG_JTAG_UART_TICKS—Logging interval in ticks. Default is <i>&lt;ticks_per_second&gt; / 10</i>.</li> <li>■ ALT_LOG_JTAG_UART_TICKS_DIVISOR—Specifies the number of logs per second. The default is 10. When you modify ALT_LOG_JTAG_UART_TICKS_DIVISOR, ALT_LOG_JTAG_UART_TICKS is recalculated.</li> </ul>
	Sample Output	JTAG Alarm: SW CirBuf = 0, HW FIFO wspace=45 AC=0 WI=0 RI=0 WE=0 RE=1
JTAG interrupt service routine (ISR) log	Purpose	Prints out a message every time the JTAG UART near-empty interrupt triggers. Message contains the same JTAG UART information as in the JTAG startup log.
	Preprocessor symbol	ALT_LOG_JTAG_UART_ISR_ON_FLAG_SETTING
	Modifiers	None
	Sample Output	JTAG IRQ: SW CirBuf = -20, HW FIFO wspace=64 AC=0 WI=1 RI=0 WE=1 RE=1
Boot log	Purpose	Prints out messages tracing the software boot process. The boot log is turned on by default when Altera logging is enabled.
	Preprocessor symbol	ALT_LOG_BOOT_ON_FLAG_SETTING
	Modifiers	None
	Sample Output	Refer to <a href="#">“Enabling Altera Logging” on page 6-10</a> .

Setting a preprocessor flag to 1 enables the corresponding option. Any value other than 1 disables the option.

Several options have modifiers, which are additional preprocessor symbols controlling details of how the options work. For example, the system clock log’s modifiers control the logging interval. Option modifiers are also listed in [Table 6-3](#). An option’s modifiers are meaningful only when the option is enabled.

### Logging Levels

An additional preprocessor symbol, ALT\_LOG\_FLAGS, can be set to provide some grouping for the extra logging options. ALT\_LOG\_FLAGS implements logging levels based on performance impact. With higher logging levels, the Altera logging options take more processor time. ALT\_LOG\_FLAGS levels are defined in [Table 6-4](#).

**Table 6-4.** Altera Logging Levels

Logging Level	Logging
0	Boot log (default)
1	Level 0 plus system clock log and JTAG startup log
2	Level 1 plus JTAG interval log and write echo
3	Level 2 plus JTAG ISR log
-1	Silent mode—No Altera logging

**Note to Table 6-4:**

- (1) You can use logging level -1 to turn off logging without changing the program footprint. The logging code is still present in your executable image, as determined by other logging options chosen. This is useful when you wish to switch the log output on or off without disturbing the memory map.

Because each logging option is controlled by an independent preprocessor symbol, individual options in the logging levels can be overridden.

**Example: Creating a BSP with Logging**

**Example 6-6** creates a HAL BSP with Altera logging enabled and the following options in addition to the default boot log:

- System clock log
- JTAG startup log
- JTAG interval log, logging twice a second
- No write echo

**Example 6-6.** BSP With Logging

```
nios2-bsp hal my_bsp ../my_hardware.sopcinfo \
--set hal.log_port uart1 \
--set hal.make.bsp_cflags_user_flags \
-DALT_LOG_FLAGS=2 \
-DALT_LOG_WRITE_ON_FLAG_SETTING=0 \
-DALT_LOG_JTAG_UART_TICKS_DIVISOR=2
```

The `-DALT_LOG_FLAGS=2` argument adds `-DALT_LOG_FLAGS=2` to the `ALT_CPP_FLAGS` make variable in `public.mk`.

**Custom Logging Messages**

You can add custom messages that are sent to the Altera logging device. To define a custom message, include the header file `alt_log_printf.h` in your C source file as follows:

```
#include "sys/alt_log_printf.h"
```

Then use the following macro function:

```
ALT_LOG_PRINTF(const char *format, ...)
```

This C preprocessor macro is a pared-down version of `printf()`. The format argument supports most `printf()` options. It supports `%c`, `%d`, `%I`, `%o`, `%s`, `%u`, `%x`, and `%X`, as well as some precision and spacing modifiers, such as `%-9.3o`. It does not support floating point formats, such as `%f` or `%g`. This function is not compiled if Altera logging is not enabled.

If you want your custom logging message be controlled by Altera logging preprocessor options, use the appropriate Altera logging option preprocessor flags from [Table 6-4](#), or [Table 6-3 on page 6-11](#). [Example 6-7](#) illustrates two ways to implement logging options with custom logging messages.

#### Example 6-7. Using Preprocessor Flags

```
/* The following example prints "Level 2 logging message" if
   logging is set to level 2 or higher */
#if ( ALT_LOG_FLAGS >= 2 )
    ALT_LOG_PRINTF ( "Level 2 logging message" );
#endif

/* The following example prints "Boot logging message" if boot logging
   is turned on */
#if ( ALT_LOG_BOOT_ON_FLAG_SETTING == 1)
    ALT_LOG_PRINTF ( "Boot logging message" );
#endif
```

### Altera Logging Files

[Table 6-5](#) lists HAL source files which implement Altera logging functions.

**Table 6-5.** HAL Implementation Files for Altera Logging

Location (1)	File Name
components/altera_hal/HAL/inc/sys/	alt_log_printf.h
components/altera_hal/HAL/src/	alt_log_printf.c
components/altera_nios2/HAL/src/	alt_log_macro.S

**Note to [Table 6-5](#):**

(1) All file locations are relative to `$SOPC_KIT_NIOS2`.

[Table 6-6](#) lists HAL source files which use Altera logging functions. These files implement the logging options listed in [table \[Table 6-3 on page 6-11\]\(#\)](#). They also serve as examples of logging usage.

**Table 6-6.** HAL Example Files for Altera Logging

Location (1)	File Name
components/altera_avalon_jtag_uart/HAL/src/	altera_avalon_jtag_uart.c
components/altera_avalon_timer/HAL/src/	altera_avalon_timer_sc.c
components/altera_hal/HAL/src/	alt_exit.c
components/altera_hal/HAL/src/	alt_main.c
components/altera_hal/HAL/src/	alt_write.c
components/altera_nios2/HAL/src/	crt0.S

**Note to Table 6-6:**

(1) All file locations are relative to \$SOPC\_KIT\_NIOS2.

## Using File Subsystems

The HAL generic device model for file subsystems allows access to data stored in an associated storage device using the C standard library file I/O functions. For example, the Altera read-only zip file system provides read-only access to a file system stored in flash memory.

A file subsystem is responsible for managing all file I/O access beneath a given mount point. For example, if a file subsystem is registered with the mount point **/mnt/rozipfs**, all file access beneath this directory, such as `fopen( "/mnt/rozipfs/myfile", "r" )`, is directed to that file subsystem.

As with character mode devices, you can manipulate files in a file subsystem using the C file I/O functions defined in **file.h**, such as `fopen( )` and `fread( )`.



For more information about the use of file I/O functions, refer to the newlib C library documentation installed with the Nios II EDS. On the Windows Start menu, click **Programs > Altera > Nios II <version> > Nios II EDS <version> Documentation**.

## Host-Based File System

The host-based file system enables programs executing on a target board to read and write files stored on the host computer. The Nios II Studio transmits file data over the Altera download cable. Your program accesses the host based file system using the ANSI C standard library I/O functions, such as `fopen( )` and `fread( )`. The host-based file system is a software package which you add to your BSP.

The following features and restrictions apply to the host based file system:

- The host-based file system makes the Nios II C/C++ application project directory and its subdirectories available to the hardware abstraction layer (HAL) file system on the target hardware.
- The target processor can access any file in the project directory. Be careful not to corrupt project source files.

- The host-based file system only operates while debugging a project. It cannot be used for run sessions.
- Host file data travels between host and target serially through the Altera download cable, and therefore file access time is relatively slow. Depending on your host and target system configurations, it can take several milliseconds per call to the host. For higher performance, use buffered I/O function such as `fread()` and `fwrite()`, and increase the buffer size for large files.

You configure the host-based file system using the Nios II BSP Editor. The host-based file system has one setting: the mount point, which specifies the mount point within the HAL file system. For example, if you name the mount point `/mnt/host` and the project directory on your host computer is `/software/project1`, in a HAL-based program, the following code opens the file `/software/project1/datafile.dat`:

```
fopen( "/mnt/host/datafile.dat", "r" );
```

## Using Timer Devices

Timer devices are hardware peripherals that count clock ticks and can generate periodic interrupt requests. You can use a timer device to provide a number of time-related facilities, such as the HAL system clock, alarms, the time-of-day, and time measurement. To use the timer facilities, the Nios II processor system must include a timer peripheral in hardware.

The HAL API provides two types of timer device drivers:

- System clock driver—Supports alarms, such as you would use in a scheduler.
- Timestamp driver—Supports high-resolution time measurement.

An individual timer peripheral can behave as either a system clock or a timestamp, but not both.



The HAL-specific API functions for accessing timer devices are defined in `sys/alt_alarm.h` and `sys/alt_timestamp.h`.

## System Clock Driver

The HAL system clock driver provides a periodic heartbeat, causing the system clock to increment on each beat. Software can use the system clock facilities to execute functions at specified times, and to obtain timing information. You select a specific hardware timer peripheral as the system clock device by manipulating BSP settings.


For details about how to control BSP settings, refer to [“HAL BSP Settings” on page 6-2](#).

The HAL provides implementations of the following standard UNIX functions: `gettimeofday()`, `settimeofday()`, and `times()`. The times returned by these functions are based on the HAL system clock.

The system clock measures time in clock ticks. For embedded engineers who deal with both hardware and software, do not confuse the HAL system clock with the clock signal driving the Nios II processor hardware. The period of a HAL system clock tick is generally much longer than the hardware system clock. `system.h` defines the clock tick frequency.

At runtime, you can obtain the current value of the system clock by calling the `alt_nticks()` function. This function returns the elapsed time in system clock ticks since reset. You can get the system clock rate, in ticks per second, by calling the function `alt_ticks_per_second()`. The HAL timer driver initializes the tick frequency when it creates the instance of the system clock.

The standard UNIX function `gettimeofday()` is available to obtain the current time. You must first calibrate the time of day by calling `settimeofday()`. In addition, you can use the `times()` function to obtain information about the number of elapsed ticks. The prototypes for these functions appear in **times.h**.

 For more information about the use of these functions, refer to the *HAL API Reference* chapter of the *Nios II Software Developer's Handbook*.

## Alarms

You can register functions to be executed at a specified time using the HAL alarm facility. A software program registers an alarm by calling the function `alt_alarm_start()`:

```
int alt_alarm_start (alt_alarm* alarm,
                    alt_u32   nticks,
                    alt_u32   (*callback) (void* context),
                    void*     context);
```


The function `callback()` is called after `nticks` have elapsed. The input argument `context` is passed as the input argument to `callback()` when the call occurs. The HAL does not use the `context` parameter. It is only used as a parameter to the `callback()` function.

Your code must allocate the `alt_alarm` structure, pointed to by the input argument `alarm`. This data structure must have a lifetime that is at least as long as that of the alarm. The best way to allocate this structure is to declare it as a static or global. `alt_alarm_start()` initializes `*alarm`.

The callback function can reset the alarm. The return value of the registered callback function is the number of ticks until the next call to `callback()`. A return value of zero indicates that the alarm should be stopped. You can manually cancel an alarm by calling `alt_alarm_stop()`.

One alarm is created for each call to `alt_alarm_start()`. Multiple alarms can run simultaneously.

Alarm callback functions execute in an exception context. This imposes functional restrictions which you must observe when writing an alarm callback.

 For more information about the use of these functions, refer to the *Exception Handling* chapter of the *Nios II Software Developer's Handbook*.

The code fragment in **Example 6-8** demonstrates registering an alarm for a periodic callback every second.

**Example 6-8.** Using a Periodic Alarm Callback Function

---

```

#include <stddef.h>
#include <stdio.h>
#include "sys/alt_alarm.h"
#include "alt_types.h"

/*
 * The callback function.
 */

alt_u32 my_alarm_callback (void* context)
{
    /* This function is called once per second */
    return alt_ticks_per_second();
}

...

/* The alt_alarm must persist for the duration of the alarm. */
static alt_alarm alarm;

...

if (alt_alarm_start (&alarm,
                    alt_ticks_per_second(),
                    my_alarm_callback,
                    NULL) < 0)
{
    printf ("No system clock available\n");
}

```

---

## Timestamp Driver

Sometimes you want to measure time intervals with a degree of accuracy greater than that provided by HAL system clock ticks. The HAL provides high resolution timing functions using a timestamp driver. A timestamp driver provides a monotonically increasing counter that you can sample to obtain timing information. The HAL only supports one timestamp driver in the system.

You specify a hardware timer peripheral as the timestamp device by manipulating BSP settings. The Altera-provided timestamp driver uses the timer that you specify.


If a timestamp driver is present, the following functions are available:

- `alt_timestamp_start()`
- `alt_timestamp()`

Calling `alt_timestamp_start()` starts the counter running. Subsequent calls to `alt_timestamp()` return the current value of the timestamp counter. Calling `alt_timestamp_start()` again resets the counter to zero. The behavior of the timestamp driver is undefined when the counter reaches  $(2^{32} - 1)$ .

You can obtain the rate at which the timestamp counter increments by calling the function `alt_timestamp_freq()`. This rate is typically the hardware frequency of the Nios II processor system—usually millions of cycles per second. The timestamp drivers are defined in the `alt_timestamp.h` header file.



 For more information about the use of these functions, refer to the *HAL API Reference* chapter of the *Nios II Software Developer's Handbook*.

The code fragment in [Example 6-9](#) shows how you can use the timestamp facility to measure code execution time.

---

**Example 6-9.** Using the Timestamp to Measure Code Execution Time

---

```
#include <stdio.h>
#include "sys/alt_timestamp.h"
#include "alt_types.h"

int main (void)
{
    alt_u32 time1;
    alt_u32 time2;
    alt_u32 time3;

    if (alt_timestamp_start() < 0)
    {
        printf ("No timestamp device available\n");
    }
    else
    {
        time1 = alt_timestamp();
        func1(); /* first function to monitor */
        time2 = alt_timestamp();
        func2(); /* second function to monitor */
        time3 = alt_timestamp();

        printf ("time in func1 = %u ticks\n",
            (unsigned int) (time2 - time1));
        printf ("time in func2 = %u ticks\n",
            (unsigned int) (time3 - time2));
        printf ("Number of ticks per second = %u\n",
            (unsigned int) alt_timestamp_freq());
    }
    return 0;
}
```

---

## Using Flash Devices

The HAL provides a generic device model for nonvolatile flash memory devices. Flash memories use special programming protocols to store data. The HAL API provides functions to write data to flash memory. For example, you can use these functions to implement a flash-based file subsystem.

The HAL API also provides functions to read flash, although it is generally not necessary. For most flash devices, programs can treat the flash memory space as simple memory when reading, and do not need to call special HAL API functions. If the flash device has a special protocol for reading data, such as the Altera erasable programmable configurable serial (EPCS) configuration device, you must use the HAL API to both read and write data.

This section describes the HAL API for the flash device model. The following two APIs provide two different levels of access to the flash:

- Simple flash access—Functions that write buffers to flash and read them back at the block level. In writing, if the buffer is less than a full block, these functions erase preexisting flash data above and below the newly written data.
- Fine-grained flash access—Functions that write buffers to flash and read them back at the buffer level. In writing, if the buffer is less than a full block, these functions preserve preexisting flash data above and below the newly written data. This functionality is generally required for managing a file subsystem.

The API functions for accessing flash devices are defined in `sys/alt_flash.h`.



For more information about the use of these functions, refer to the *HAL API Reference* chapter of the *Nios II Software Developer's Handbook*. You can get details about the Common Flash Interface, including the organization of common flash interface (CFI) erase regions and blocks, from JEDEC ([www.jedec.org](http://www.jedec.org)). You can find the CFI standard by searching for document JESD68.

## Simple Flash Access

This interface consists of the functions `alt_flash_open_dev()`, `alt_write_flash()`, `alt_read_flash()`, and `alt_flash_close_dev()`. The code “Using the Simple Flash API Functions” on page 6-22 shows the use of all of these functions in one code example. You open a flash device by calling `alt_flash_open_dev()`, which returns a file handle to a flash device. This function takes a single argument that is the name of the flash device, as defined in `system.h`.

After you obtain a handle, you can use the `alt_write_flash()` function to write data to the flash device. The prototype is:

```
int alt_write_flash( alt_flash_fd* fd,
                    int           offset,
                    const void*   src_addr,
                    int           length )
```

A call to this function writes to the flash device identified by the handle `fd`. The driver writes the data starting at `offset` bytes from the base of the flash device. The data written comes from the address pointed to by `src_addr`, and the amount of data written is `length`.

There is also an `alt_read_flash()` function to read data from the flash device. The prototype is:

```
int alt_read_flash( alt_flash_fd* fd,
                   int           offset,
                   void*         dest_addr,
                   int           length )
```

A call to `alt_read_flash()` reads from the flash device with the handle `fd`, `offset` bytes from the beginning of the flash device. The function writes the data to location pointed to by `dest_addr`, and the amount of data read is `length`. For most flash devices, you can access the contents as standard memory, making it unnecessary to use `alt_read_flash()`.

The function `alt_flash_close_dev()` takes a file handle and closes the device. The prototype for this function is:

```
void alt_flash_close_dev(alt_flash_fd* fd )
```

The code in [Example 6-10](#) shows the use of simple flash API functions to access a flash device named `/dev/ext_flash`, as defined in `system.h`.

## Block Erasure or Corruption

Generally, flash memory is divided into blocks. `alt_write_flash()` might need to erase the contents of a block before it can write data to it. In this case, it makes no attempt to preserve the existing contents of the block. This action can lead to unexpected data corruption (erasure), if you are performing writes that do not fall on block boundaries. If you wish to preserve existing flash memory contents, use the fine-grained flash functions. These are discussed in the following section.

[Table 6-7 on page 6-23](#) shows how you can cause unexpected data corruption by writing using the simple flash access functions. [Table 6-7](#) shows the example of an 8 Kbyte flash memory comprising two 4 Kbyte blocks. First write 5 Kbytes of all `0xAA` to flash memory at address `0x0000`, and then write 2 Kbytes of all `0xBB` to address `0x1400`. After the first write succeeds (at time `t(2)`), the flash memory contains 5 Kbyte of `0xAA`, and the rest is empty (that is, `0xFF`). Then the second write begins, but before writing to the second block, the block is erased. At this point, `t(3)`, the flash contains 4 Kbyte of `0xAA` and 4 Kbyte of `0xFF`. After the second write finishes, at time `t(4)`, the 2 Kbyte of `0xFF` at address `0x1000` is corrupted.

## Fine-Grained Flash Access

Three additional functions provide complete control for writing flash contents at the highest granularity:

- `alt_get_flash_info()`
- `alt_erase_flash_block()`
- `alt_write_flash_block()`

By the nature of flash memory, you cannot erase a single address in a block. You must erase (that is, set to all ones) an entire block at a time. Writing to flash memory can only change bits from 1 to 0; to change any bit from 0 to 1, you must erase the entire block along with it.

Therefore, to alter a specific location in a block while leaving the surrounding contents unchanged, you must read out the entire contents of the block to a buffer, alter the value(s) in the buffer, erase the flash block, and finally write the whole block-sized buffer back to flash memory. The fine-grained flash access functions automate this process at the flash block level.

**Example 6-10.** Using the Simple Flash API Functions

---

```

#include <stdio.h>
#include <string.h>
#include "sys/alt_flash.h"
#define BUF_SIZE 1024

int main ()
{
    alt_flash_fd* fd;
    int          ret_code;
    char          source[BUF_SIZE];
    char          dest[BUF_SIZE];

    /* Initialize the source buffer to all 0xAA */
    memset(source, 0xAA, BUF_SIZE);

    fd = alt_flash_open_dev("/dev/ext_flash");
    if (fd!=NULL)
    {
        ret_code = alt_write_flash(fd, 0, source, BUF_SIZE);
        if (ret_code==0)
        {
            ret_code = alt_read_flash(fd, 0, dest, BUF_SIZE);
            if (ret_code==0)
            {
                /*
                 * Success.
                 * At this point, the flash is all 0xAA and we
                 * should have read that all back to dest
                 */
            }
        }
        alt_flash_close_dev(fd);
    }
    else
    {
        printf("Can't open flash device\n");
    }
    return 0;
}

```

---

`alt_get_flash_info()` gets the number of erase regions, the number of erase blocks in each region, and the size of each erase block. The function prototype is as follows:

```

int alt_get_flash_info (
    alt_flash_fd*  fd,
    flash_region** info,
    int*           number_of_regions )

```

If the call is successful, on return the address pointed to by `number_of_regions` contains the number of erase regions in the flash memory, and `*info` points to an array of `flash_region` structures. This array is part of the file descriptor.

**Table 6-7.** Example of Writing Flash and Causing Unexpected Data Corruption

Address	Block	Time t(0)	Time t(1)	Time t(2)	Time t(3)	Time t(4)
		Before First Write	First Write		Second Write	
			After Erasing Block(s)	After Writing Data 1	After Erasing Block(s)	After Writing Data 2
0x0000	1	??	FF	AA	AA	AA
0x0400	1	??	FF	AA	AA	AA
0x0800	1	??	FF	AA	AA	AA
0x0C00	1	??	FF	AA	AA	AA
0x1000	2	??	FF	AA	FF	FF (1)
0x1400	2	??	FF	FF	FF	BB
0x1800	2	??	FF	FF	FF	BB
0x1C00	2	??	FF	FF	FF	FF

**Note to Table 6-7:**

(1) Unintentionally cleared to FF during erasure for second write.

The `flash_region` structure is defined in `sys/alt_flash_types.h`. The data structure is defined as follows:

```
typedef struct flash_region
{
    int offset;           /* Offset of this region from start of the flash */
    int region_size;      /* Size of this erase region */
    int number_of_blocks; /* Number of blocks in this region */
    int block_size;       /* Size of each block in this erase region */
}flash_region;
```

With the information obtained by calling `alt_get_flash_info()`, you are in a position to erase or program individual blocks of the flash device.

`alt_erase_flash()` erases a single block in the flash memory. The function prototype is as follows:

```
int alt_erase_flash_block ( alt_flash_fd* fd, int offset, int length )
```

The flash memory is identified by the handle `fd`. The block is identified as being `offset` bytes from the beginning of the flash memory, and the block size is passed in `length`.

`alt_write_flash_block()` writes to a single block in the flash memory. The prototype is:

```
int alt_write_flash_block( alt_flash_fd* fd,
                           int           block_offset,
                           int           data_offset,
                           const void    *data,
                           int           length)
```

This function writes to the flash memory identified by the handle `fd`. It writes to the block located `block_offset` bytes from the start of the flash device. The function writes `length` bytes of data from the location pointed to by `data` to the location `data_offset` bytes from the start of the flash device.



These program and erase functions do not perform address checking, and do not verify whether a write operation spans into the next block. You must pass in valid information about the blocks to program or erase.

The code in [Example 6-11](#) on [page 6-24](#) demonstrates the use of the fine-grained flash access functions.

#### **Example 6-11.** Using the Fine-Grained Flash Access API Functions

---

```
#include <string.h>
#include "sys/alt_flash.h"
#include "stdtypes.h"
#include "system.h"#define BUF_SIZE 100

int main (void)
{
    flash_region* regions;
    alt_flash_fd* fd;
    int          number_of_regions;
    int          ret_code;
    char         write_data[BUF_SIZE];

    /* Set write_data to all 0xa */
    memset(write_data, 0xA, BUF_SIZE);

    fd = alt_flash_open_dev(EXT_FLASH_NAME);

    if (fd)
    {
        ret_code = alt_get_flash_info(fd, &regions, &number_of_regions);

        if (number_of_regions && (regions->offset == 0))
        {
            /* Erase the first block */
            ret_code = alt_erase_flash_block(fd,
                                           regions->offset,
                                           regions->block_size);

            if (ret_code == 0)
            {
                /*
                 * Write BUF_SIZE bytes from write_data 100 bytes to
                 * the first block of the flash
                 */
                ret_code = alt_write_flash_block (
                    fd,
                    regions->offset,
                    regions->offset+0x100,
                    write_data,
                    BUF_SIZE );
            }
        }
    }
    return 0;
}
```

---

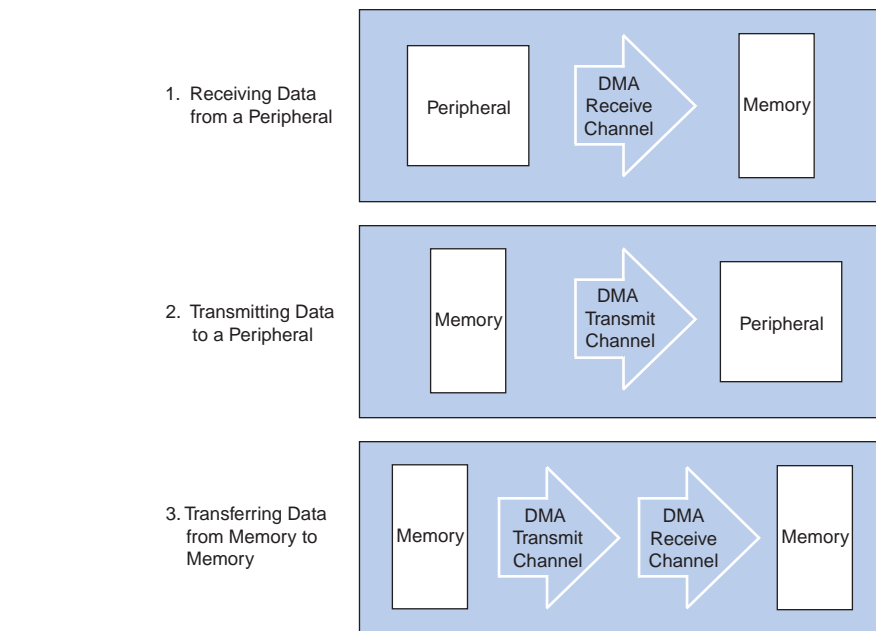
## Using DMA Devices

The HAL provides a device abstraction model for direct memory access (DMA) devices. These are peripherals that perform bulk data transactions from a data source to a destination. Sources and destinations can be memory or another device, such as an Ethernet connection.

In the HAL DMA device model, there are two categories of DMA transactions: transmit and receive. The HAL provides two device drivers to implement transmit channels and receive channels. A transmit channel takes data in a source buffer and transmits it to a destination device. A receive channel receives data from a device and deposits it in a destination buffer. Depending on the implementation of the underlying hardware, software might have access to only one of these two endpoints.

Figure 6-2 shows the three basic types of DMA transactions. Copying data from memory to memory involves both receive and transmit DMA channels simultaneously.

**Figure 6-2.** Three Basic Types of DMA Transactions



The API for access to DMA devices is defined in `sys/alt_dma.h`.

For more information about the use of these functions, refer to the *HAL API Reference* chapter of the *Nios II Software Developer's Handbook*.

DMA devices operate on the contents of physical memory, therefore when reading and writing data you must consider cache interactions.

For more information about cache memory, refer to the *Cache and Tightly-Coupled Memory* chapter of the *Nios II Software Developer's Handbook*.

## DMA Transmit Channels

DMA transmit requests are queued using a DMA transmit device handle. To obtain a handle, use the function `alt_dma_txchan_open()`. This function takes a single argument, the name of a device to use, as defined in **system.h**.

The code in [Example 6-12](#) shows how to obtain a handle for a DMA transmit device `dma_0`.

---

### Example 6-12. Obtaining a File Handle for a DMA Device

---

```
#include <stddef.h>
#include "sys/alt_dma.h"

int main (void)
{
    alt_dma_txchan tx;

    tx = alt_dma_txchan_open ("/dev/dma_0");
    if (tx == NULL)
    {
        /* Error */
    }
    else
    {
        /* Success */
    }
    return 0;
}
```

---

You can use this handle to post a transmit request using `alt_dma_txchan_send()`. The prototype is:

```
typedef void (alt_txchan_done)(void* handle);

int alt_dma_txchan_send (alt_dma_txchan    dma,
                        const void*        from,
                        alt_u32            length,
                        alt_txchan_done*    done,
                        void*              handle);
```

Calling `alt_dma_txchan_send()` posts a transmit request to channel `dma`. Argument `length` specifies the number of bytes of data to transmit, and argument `from` specifies the source address. The function returns before the full DMA transaction completes. The return value indicates whether the request is successfully queued. A negative return value indicates that the request failed. When the transaction completes, the user-supplied function `done` is called with argument `handle` to provide notification.

Two additional functions are provided for manipulating DMA transmit channels: `alt_dma_txchan_space()`, and `alt_dma_txchan_ioctl()`. The `alt_dma_txchan_space()` function returns the number of additional transmit requests that can be queued to the device. The `alt_dma_txchan_ioctl()` function performs device-specific manipulation of the transmit device.





If you are using the Avalon Memory-Mapped® (Avalon-MM) DMA device to transmit to hardware (not memory-to-memory transfer), call the `alt_dma_txchan_ioctl()` function with the request argument set to `ALT_DMA_TX_ONLY_ON`.



For further information, refer to the *HAL API Reference* chapter of the *Nios II Software Developer's Handbook*.

## DMA Receive Channels

DMA receive channels operate similarly to DMA transmit channels. Software can obtain a handle for a DMA receive channel using the `alt_dma_rxchan_open()` function. You can then use the `alt_dma_rxchan_prepare()` function to post receive requests. The prototype for `alt_dma_rxchan_prepare()` is:

```
typedef void (alt_rxchan_done)(void* handle, void* data);

int alt_dma_rxchan_prepare (alt_dma_rxchan dma,
                           void* data,
                           alt_u32 length,
                           alt_rxchan_done* done,
                           void* handle);
```

A call to this function posts a receive request to channel `dma`, for up to `length` bytes of data to be placed at address `data`. This function returns before the DMA transaction completes. The return value indicates whether the request is successfully queued. A negative return value indicates that the request failed. When the transaction completes, the user-supplied function `done()` is called with argument `handle` to provide notification and a pointer to the receive data.

Certain errors can prevent the DMA transfer from completing. Typically this is caused by a catastrophic hardware failure; for example, if a component involved in the transfer fails to respond to a read or write request. If the DMA transfer does not complete (that is, less than `length` bytes are transferred), function `done()` is never called.

Two additional functions are provided for manipulating DMA receive channels: `alt_dma_rxchan_depth()` and `alt_dma_rxchan_ioctl()`.



If you are using the Avalon-MM DMA device to receive from hardware (not memory-to-memory transfer), call the `alt_dma_rxchan_ioctl()` function with the request argument set to `ALT_DMA_RX_ONLY_ON`.

`alt_dma_rxchan_depth()` returns the maximum number of receive requests that can be queued to the device. `alt_dma_rxchan_ioctl()` performs device-specific manipulation of the receive device.



For further details, refer to the *HAL API Reference* chapter of the *Nios II Software Developer's Handbook*.

The code in [Example 6-13](#) shows a complete example application that posts a DMA receive request, and blocks in `main()` until the transaction completes.

**Example 6-13. A DMA Transaction on a Receive Channel**


---

```

#include <stdio.h>
#include <stddef.h>
#include <stdlib.h>
#include "sys/alt_dma.h"
#include "alt_types.h"

/* flag used to indicate the transaction is complete */
volatile int dma_complete = 0;

/* function that is called when the transaction completes */
void dma_done (void* handle, void* data)
{
    dma_complete = 1;
}

int main (void)
{
    alt_u8 buffer[1024];
    alt_dma_rxchan rx;

    /* Obtain a handle for the device */
    if ((rx = alt_dma_rxchan_open ("/dev/dma_0")) == NULL)
    {
        printf ("Error: failed to open device\n");
        exit (1);
    }
    else
    {
        /* Post the receive request */
        if (alt_dma_rxchan_prepare (rx, buffer, 1024, dma_done, NULL) < 0)
        {
            printf ("Error: failed to post receive request\n");
            exit (1);
        }

        /* Wait for the transaction to complete */
        while (!dma_complete);
        printf ("Transaction complete\n");
        alt_dma_rxchan_close (rx);
    }
    return 0;
}

```

---

**Memory-to-Memory DMA Transactions**

Copying data from one memory buffer to another buffer involves both receive and transmit DMA drivers. The code in [Example 6-14](#) shows the process of queuing up a receive request followed by a transmit request to achieve a memory-to-memory DMA transaction.

#### Example 6-14. Copying Data from Memory to Memory (Part 1 of 2)

---

```
#include <stdio.h>
#include <stdlib.h>

#include "sys/alt_dma.h"
#include "system.h"

static volatile int rx_done = 0;

/*
 * Callback function that obtains notification that the data
 * is received.
 */

static void done (void* handle, void* data)
{
    rx_done++;
}

/*
 *
 */

int main (int argc, char* argv[], char* envp[])
{
    int rc;

    alt_dma_txchan txchan;
    alt_dma_rxchan rxchan;

    void* tx_data = (void*) 0x901000; /* pointer to data to send */
    void* rx_buffer = (void*) 0x902000; /* pointer to rx buffer */

    /* Create the transmit channel */

    if ((txchan = alt_dma_txchan_open("/dev/dma_0")) == NULL)
    {
        printf ("Failed to open transmit channel\n");
        exit (1);
    }

    /* Create the receive channel */

    if ((rxchan = alt_dma_rxchan_open("/dev/dma_0")) == NULL)
    {
        printf ("Failed to open receive channel\n");
        exit (1);
    }

    /* Post the transmit request */

    if ((rc = alt_dma_txchan_send (txchan,
                                   tx_data,
                                   128,
                                   NULL,
                                   NULL)) < 0)
    {
        printf ("Failed to post transmit request, reason = %i\n", rc);
        exit (1);
    }

    /* Continued... */
}
```

---

**Example 6-14.** Copying Data from Memory to Memory (Part 2 of 2)

```
/* Post the receive request */

if ((rc = alt_dma_rxchan_prepare (rxchan,
                                rx_buffer,
                                128,
                                done,
                                NULL)) < 0)
{
    printf ("Failed to post read request, reason = %i\n", rc);
    exit (1);
}

/* wait for transfer to complete */

while (!rx_done);

printf ("Transfer successful!\n");

return 0;
}
```

## Using Interrupt Controllers

The HAL supports two types of interrupt controllers:

- The Nios II internal interrupt controller
- An external interrupt controller component



For information about working with interrupt controllers, refer to the *Exception Handling* chapter of the *Nios II Software Developer's Handbook*.

## Reducing Code Footprint

Code size is always a concern for embedded systems developers, because there is a cost associated with the memory device that stores code. The ability to control and reduce code size is important in controlling this cost.

The HAL environment is designed to include only those features that you request, minimizing the total code footprint. If your Nios II hardware system contains exactly the peripherals used by your program, the HAL contains only the drivers necessary to control the hardware.

The following sections describe options to consider when you need to further reduce code size. The **hello\_world\_small** example project demonstrates the use of some of these options to reduce code size to the absolute minimum.

Implementing the options in the following sections entails making changes to BSP settings. For detailed information about manipulating BSP settings, refer to “*HAL BSP Settings*” on page 6-2.

## Enable Compiler Optimizations

To enable compiler optimizations, use the `-O3` compiler optimization level for the `nios2-elf-gcc` compiler. You can specify this command-line option through a BSP setting.

With this option turned on, the Nios II compiler compiles code with the maximum optimization available, for both size and speed.



You must set this option for both the BSP and the application project.

## Use Reduced Device Drivers

Some devices provide two driver variants, a fast variant and a small variant. The feature sets provided by these two variants are device specific. The fast variant is full-featured, and the small variant provides a reduced code footprint.

By default the HAL always uses the fast driver variants. You can select the reduced device driver for all hardware components, or for an individual component, through HAL BSP settings.

Table 6-8 lists the Altera Nios II peripherals that currently provide small footprint drivers. The small footprint option might also affect other peripherals. Refer to each peripheral's data sheet for complete details of its driver's small footprint behavior.

**Table 6-8.** Altera Peripherals Offering Small Footprint Drivers

Peripheral	Small Footprint Behavior
UART	Polled operation, rather than IRQ-driven
JTAG UART	Polled operation, rather than IRQ-driven
Common flash interface controller	Driver excluded in small footprint mode
LCD module controller	Driver excluded in small footprint mode
EPCS serial configuration device	Driver excluded in small footprint mode

## Reduce the File Descriptor Pool

The file descriptors that access character mode devices and files are allocated from a file descriptor pool. You can change the size of the file descriptor pool through a BSP setting. The default is 32.

## Use `/dev/null`

At boot time, standard input, standard output, and standard error are all directed towards the null device, that is, `/dev/null`. This direction ensures that calls to `printf()` during driver initialization do nothing and therefore are harmless. After all drivers are installed, these streams are redirected to the channels configured in the HAL. The footprint of the code that performs this redirection is small, but you can eliminate it entirely by selecting `null` for `stdin`, `stdout`, and `stderr`. This selection assumes that you want to discard all data transmitted on standard out or standard error, and your program never receives input through `stdin`. You can control the assignment of `stdin`, `stdout`, and `stderr` channels by manipulating BSP settings.

## Use a Smaller File I/O Library

### Use the Small newlib C Library

The full newlib ANSI C standard library is often unnecessary for embedded systems. The GNU Compiler Collection (GCC) provides a reduced implementation of the newlib ANSI C standard library, omitting features of newlib that are often superfluous for embedded systems. The small newlib implementation requires a smaller code footprint. When you use **nios2-elf-gcc** at the command line, the **-msmallc** command-line option enables the small C library.

You can select the small newlib library through BSP settings. [Table 6–9](#) summarizes the limitations of the Nios II small newlib C library implementation.

**Table 6–9. Limitations of the Nios II Small newlib C Library (Part 1 of 2)**

Limitation	Functions Affected
No floating-point support for <code>printf()</code> family of routines. The functions listed are implemented, but <code>%f</code> and <code>%g</code> options are not supported. (1)	<code>asprintf()</code> <code>fiprintf()</code> <code>fprintf()</code> <code>iprintf()</code> <code>printf()</code> <code>siprintf()</code> <code>snprintf()</code> <code>sprintf()</code>
No floating-point support for <code>vprintf()</code> family of routines. The functions listed are implemented, but <code>%f</code> and <code>%g</code> options are not supported.	<code>vasprintf()</code> <code>vfiprintf()</code> <code>vfprintf()</code> <code>vprintf()</code> <code>vsnprintf()</code> <code>vsprintf()</code>
No support for <code>scanf()</code> family of routines. The functions listed are not supported.	<code>fscanf()</code> <code>scanf()</code> <code>sscanf()</code> <code>vfscanf()</code> <code>vscanf()</code> <code>vsscanf()</code>
No support for seeking. The functions listed are not supported.	<code>fseek()</code> <code>ftell()</code>
No support for opening/closing <code>FILE *</code> . Only pre-opened <code>stdout</code> , <code>stderr</code> , and <code>stdin</code> are available. The functions listed are not supported.	<code>fopen()</code> <code>fclose()</code> <code>fdopen()</code> <code>fcloseall()</code> <code>fileno()</code>

**Table 6–9. Limitations of the Nios II Small newlib C Library (Part 2 of 2)**

Limitation	Functions Affected
No buffering of <b>stdio.h</b> output routines.	<p>functions supported with no buffering:</p> <pre>fiprintf() fputc() fputs() perror() putc() putchar() puts() printf()</pre> <p>functions not supported:</p> <pre>setbuf() setvbuf()</pre>
No <b>stdio.h</b> input routines. The functions listed are not supported.	<pre>fgetc() gets() fscanf() getc() getchar() gets() getw() scanf()</pre>
No support for locale.	<pre>setlocale() localeconv()</pre>
No support for C++, because the functions listed in this table are not supported.	

**Note to Table 6–9:**

(1) These functions are a Nios II extension. GCC does not implement them in the small newlib C library.



The small newlib C library does not support MicroC/OS-II.



For details about the GCC small newlib C library, refer to the newlib documentation installed with the Nios II EDS. On the Windows **Start** menu, click **Programs > Altera > Nios II > Nios II Documentation**.



The Nios II implementation of the small newlib C library differs slightly from GCC. [Table 6–9](#) provides details about the differences.

### Use UNIX-Style File I/O

If you need to reduce the code footprint further, you can omit the newlib C library, and use the UNIX-style API. For details, refer to [“UNIX-Style Interface” on page 6–5](#).

The Nios II EDS provides ANSI C file I/O, in the newlib C library, because there is a per-access performance overhead associated with accessing devices and files using the UNIX-style file I/O functions. The ANSI C file I/O provides buffered access, thereby reducing the total number of hardware I/O accesses performed. Also the ANSI C API is more flexible and therefore easier to use. However, these benefits are gained at the expense of code footprint.

### Emulate ANSI C Functions

If you choose to omit the full implementation of newlib, but you need a limited number of ANSI-style functions, you can implement them easily using UNIX-style functions. The code in [Example 6-15](#) shows a simple, unbuffered implementation of `getchar()`.

#### Example 6-15. Unbuffered `getchar()`

---

```
/* getchar: unbuffered single character input */
int getchar ( void )
{
    char c;
    return ( read ( 0, &c, 1 ) == 1 ) ? ( unsigned char ) c : EOF;
}
```

---



This example is from *The C Programming Language, Second Edition*, by Brian W. Kernighan and Dennis M. Ritchie. This standard textbook contains many other useful functions.

## Use the Lightweight Device Driver API

The lightweight device driver API allows you to minimize the overhead of accessing device drivers. It has no direct effect on the size of the drivers themselves, but lets you eliminate driver API features which you might not need, reducing the overall size of the HAL code.

The lightweight device driver API is available for character-mode devices. The following device drivers support the lightweight device driver API:

- JTAG UART
- UART
- Optrex 16207 LCD

For these devices, the lightweight device driver API conserves code space by eliminating the dynamic file descriptor table and replacing it with three static file descriptors, corresponding to `stdin`, `stdout`, and `stderr`. Library functions related to opening, closing, and manipulating file descriptors are unavailable, but all other library functionality is available. You can refer to `stdin`, `stdout`, and `stderr` as you would to any other file descriptor. You can also refer to the following predefined file numbers:

```
#define STDIN 0
#define STDOUT 1
#define STDERR 2
```



This option is appropriate if your program has a limited need for file I/O. The Altera host-based file system and the Altera read-only zip file system are not available with the reduced device driver API. You can select the reduced device drivers through BSP settings.

By default, the lightweight device driver API is disabled.



For further details about the lightweight device driver API, refer to the *Developing Device Drivers for the Hardware Abstraction Layer* chapter of the *Nios II Software Developer's Handbook*.

## Use the Minimal Character-Mode API

If you can limit your use of character-mode I/O to very simple features, you can reduce code footprint by using the minimal character-mode API. This API includes the following functions:

- `alt_printf()`
- `alt_putchar()`
- `alt_putstr()`
- `alt_getchar()`

These functions are appropriate if your program only needs to accept command strings and send simple text messages. Some of them are helpful only in conjunction with the lightweight device driver API, discussed in “[Use the Lightweight Device Driver API](#)” on page 6-34.

To use the minimal character-mode API, include the header file `sys/alt_stdio.h`.

The following sections outline the effects of the functions on code footprint.

### **`alt_printf()`**

This function is similar to `printf()`, but supports only the `%c`, `%s`, `%x`, and `%%` substitution strings. `alt_printf()` takes up substantially less code space than `printf()`, regardless whether you select the lightweight device driver API. `alt_printf()` occupies less than 1Kbyte with compiler optimization level `-O2`.

### **`alt_putchar()`**

Equivalent to `putchar()`. In conjunction with the lightweight device driver API, this function further reduces code footprint. In the absence of the lightweight API, it calls `putchar()`.

### **`alt_putstr()`**

Similar to `puts()`, except that it does not append a newline character to the string. In conjunction with the lightweight device driver API, this function further reduces code footprint. In the absence of the lightweight API, it calls `puts()`.

### **`alt_getchar()`**

Equivalent to `getchar()`. In conjunction with the lightweight device driver API, this function further reduces code footprint. In the absence of the lightweight API, it calls `getchar()`.



For further details about the minimal character-mode functions, refer to the *HAL API Reference* chapter of the *Nios II Software Developer's Handbook*.

## Eliminate Unused Device Drivers

If a hardware device is present in the system, by default the Nios II development flows assume the device needs drivers, and configure the HAL BSP accordingly. If the HAL can find an appropriate driver, it creates an instance of this driver. If your program never actually accesses the device, resources are being used unnecessarily to initialize the device driver.

If the hardware includes a device that your program never uses, consider removing the device from the hardware. This reduces both code footprint and FPGA resource usage.

However, there are cases when a device must be present, but runtime software does not require a driver. The most common example is flash memory. The user program might boot from flash, but not use it at runtime; thus, it does not need a flash driver.

You can selectively omit any individual driver, select a specific driver version, or substitute your own driver.



For further information about controlling driver configurations, refer to the *Nios II Software Build Tools* chapter of the *Nios II Software Developer's Handbook*.

Another way to control the device driver initialization process is to use the free-standing environment. For details, refer to “*Boot Sequence and Entry Point*” on page 6-37.

## Eliminate Unneeded Exit Code

The HAL calls the `exit()` function at system shutdown to provide a clean exit from the program. `exit()` flushes all of the C library internal I/O buffers and calls any C++ functions registered with `atexit()`. In particular, `exit()` is called on return from `main()`. Two HAL options allow you to minimize or eliminate this exit code.

### Eliminate Clean Exit

To avoid the overhead associated with providing a clean exit, your program can use the function `_exit()` in place of `exit()`. This function does not require you to change source code. You can select the `_exit()` function through a BSP setting.

### Eliminate All Exit Code

Many embedded systems never exit at all. In such cases, exit code is unnecessary. You can eliminate all exit code through a BSP setting.



If you enable this option, ensure that your `main()` function (or `alt_main()` function) does not return.

## Turn off C++ Support

By default, the HAL provides support for C++ programs, including default constructors and destructors. You can disable C++ support through a BSP setting.

## Boot Sequence and Entry Point

Normally, your program's entry point is the function `main()`. There is an alternate entry point, `alt_main()`, that you can use to gain greater control of the boot sequence. The difference between entering at `main()` and entering at `alt_main()` is the difference between hosted and free-standing applications.

### Hosted versus Free-Standing Applications

The ANSI C standard defines a hosted application as one that calls `main()` to begin execution. At the start of `main()`, a hosted application presumes the runtime environment and all system services are initialized and ready to use. This is true in the HAL environment. If you are new to Nios II programming, the HAL's hosted environment helps you come up to speed more easily, because you need not consider what devices exist in the system or how to initialize each one. The HAL initializes the whole system.

The ANSI C standard also provides for an alternate entry point that avoids automatic initialization, and assumes that the Nios II programmer initializes any needed hardware explicitly. The `alt_main()` function provides a free-standing environment, giving you complete control over the initialization of the system. The free-standing environment places on the programmer the responsibility to initialize any system features used in the program. For example, calls to `printf()` do not function correctly in the free-standing environment, unless `alt_main()` first instantiates a character-mode device driver, and redirects `stdout` to the device.



Using the free-standing environment increases the complexity of writing Nios II programs, because you assume responsibility for initializing the system. If your main interest is to reduce code footprint, you should use the suggestions described in [“Reducing Code Footprint” on page 6-30](#). It is easier to reduce the HAL BSP footprint by using BSP settings, than to use the free-standing mode.

The Nios II EDS provides examples of both free-standing and hosted programs.

### Boot Sequence for HAL-Based Programs

The HAL provides system initialization code in the C runtime library (`crt0.S`). This code performs the following boot sequence:

- Flushes the instruction and data cache.
- Configures the stack pointer.
- Configures the global pointer register.
- Initializes the BSS region to zeroes using the linker-supplied symbols `__bss_start` and `__bss_end`. These are pointers to the beginning and the end of the BSS region.
- If there is no boot loader present in the system, copies to RAM any linker section whose run address is in RAM, such as `.rdata`, `.rodata`, and `.exceptions`. Refer to [“Global Pointer Register” on page 6-42](#).
- Calls `alt_main()`.

The HAL provides a default implementation of the `alt_main()` function, which performs the following steps:

- Calls the `alt_irq_init()` function, located in **`alt_sys_init.c`**. `alt_irq_init()` **initializes the hardware interrupt controller**. The Nios II development flow creates the file **`alt_sys_init.c`** for each HAL BSP.
- Calls `ALT_OS_INIT()` to perform any necessary operating system specific initialization. For a system that does not include an operating system (OS) scheduler, this macro has no effect.
- If you are using the HAL with an operating system, initializes the `alt_fd_list_lock` semaphore, which controls access to the HAL file systems.
- Enables interrupts.
- Calls the `alt_sys_init()` function, also located in **`alt_sys_init.c`**. `alt_sys_init()` initializes all device drivers and software packages in the system.
- Redirects the C standard I/O channels (`stdin`, `stdout`, and `stderr`) to use the appropriate devices.
- Calls the C++ constructors, using the `_do_ctors()` function.
- Registers the C++ destructors to be called at system shutdown.
- Calls `main()`.
- Calls `exit()`, passing the return code of `main()` as the input argument for `exit()`.

**`alt_main.c`**, installed with the Nios II EDS, provides this default implementation. The Software Build Tools copy **`alt_main.c`** to your BSP directory.

## Customizing the Boot Sequence

You can provide your own implementation of the start-up sequence by simply defining `alt_main()` in your Nios II project. This gives you complete control of the boot sequence, and allows you to selectively enable HAL services. If your application requires an `alt_main()` entry point, you can copy the default implementation as a starting point and customize it to your needs.


Function `alt_main()` calls function `main()`. After `main()` returns, the default `alt_main()` enters an infinite loop. Alternatively, your custom `alt_main()` might terminate by calling `exit()`. Do not use a `return` statement.

The prototype for `alt_main()` is:

```
void alt_main (void)
```

The HAL build environment includes mechanisms to override default HAL BSP code. This lets you override boot loaders, as well as default device drivers and other system code, with your own implementation.

**`alt_sys_init.c`** is a generated file, which you should not modify. However, the Nios II Software Build Tools enable you to control the generated contents of **`alt_sys_init.c`**. To specify the initialization sequence in **`alt_sys_init.c`**, you manipulate the `auto_initialize` and `alt_sys_init_priority` properties of each driver, using the `set_sw_property` Tcl command.

 For more information about generated files and how to control the contents of `alt_sys_init.c`, refer to the *Nios II Software Build Tools* chapter of the *Nios II Software Developer's Handbook*. For general information about `alt_sys_init.c`, refer to the *Developing Device Drivers for the Hardware Abstraction Layer* chapter of the *Nios II Software Developer's Handbook*. For details about the `set_sw_property` Tcl command, refer to the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*.

## Memory Usage

This section describes how the HAL uses memory and arranges code, data, stack, and other logical memory sections, in physical memory.

### Memory Sections

By default, HAL-based systems are linked using a generated linker script that is created by the Nios II Software Build Tools. This linker script controls the mapping of code and data to the available memory sections. The autogenerated linker script creates standard code and data sections (`.text`, `.rodata`, `.rwdata`, and `.bss`), plus a section for each physical memory device in the system. For example, if a memory component named `sdram` is defined in the `system.h` file, there is a memory section named `.sdram`. [Figure 6-3](#) shows the organization of a typical HAL link map.

The memory devices that contain the Nios II processor's reset and exception addresses are a special case. The Nios II tools construct the 32-byte `.entry` section starting at the reset address. This section is reserved exclusively for the use of the reset handler. Similarly, the tools construct a `.exceptions` section, starting at the exception address.

In a memory device containing the reset or exception address, the linker creates a normal (nonreserved) memory section above the `.entry` or `.exceptions` section. If there is a region of memory below the `.entry` or `.exceptions` section, it is unavailable to the Nios II software. [Figure 6-3](#) illustrates an unavailable memory region below the `.exceptions` section.

### Assigning Code and Data to Memory Partitions

This section describes how to control the placement of program code and data in specific memory sections. In general, the Nios II development flow specifies a sensible default partitioning. However, you might wish to change the partitioning in special situations.

For example, to enhance performance, it is a common technique to place performance-critical code and data in RAM with fast access time. It is also common during the debug phase to reset (that is, boot) the processor from a location in RAM, but then boot from flash memory in the released version of the software. In these cases, you must specify manually which code belongs in which section.

**Figure 6-3.** Sample HAL Link Map

Physical Memory	HAL Memory Sections
	.entry
ext_flash	.ext_flash
⋮	⋮
sdram	(unused)
	.exceptions
	.text
	.rodata
	.rwdata
	.bss
	.sdram
⋮	⋮
ext_ram	.ext_ram
⋮	⋮
epcs_controller	.epcs_controller

**Simple Placement Options**

The reset handler code is always placed at the base of the `.reset` partition. The general exception funnel code is always the first code in the section that contains the exception address. By default, the remaining code and data are divided into the following output sections:

- `.text`—All remaining code
- `.rodata`—The read-only data
- `.rwdata`—Read-write data
- `.bss`—Zero-initialized data

You can control the placement of `.text`, `.rodata`, `.rwdata`, and all other memory partitions by manipulating BSP settings. For details about how to control BSP settings, refer to [“HAL BSP Settings” on page 6-2](#).

The Nios II BSP Editor is a very convenient way to manipulate the linker's memory map. The BSP Editor displays memory section and region assignments graphically, allowing you to see overlapping or unused sections of memory. The BSP Editor is available either through the Nios II Software Build Tools for Eclipse, or at the command line of the Nios II Software Build Tools.



For details, refer to the *Getting Started from the Command Line* chapter of the *Nios II Software Developer's Handbook*.

### Advanced Placement Options

In your program source code, you can specify a target memory section for each piece of code. In C or C++, you can use the `section` attribute. This attribute must be placed in a function prototype; you cannot place it in the function declaration itself. The code in [Example 6-16](#) places a variable `foo` in the memory named `ext_ram`, and the function `bar()` in the memory named `sdram`.

#### Example 6-16. Manually Assigning C Code to a Specific Memory Section

---

```
/* data should be initialized when using the section attribute */
int foo __attribute__((section (".ext_ram.rwdata"))) = 0;

void bar (void) __attribute__((section (".sdram.txt")));

void bar (void)
{
    foo++;
}
```

---

In assembly you do this using the `.section` directive. For example, all code after the following line is placed in the memory device named `ext_ram`:

```
.section .ext_ram.txt
```



The section names `ext_ram` and `sdram` are examples. You need to use section names corresponding to your hardware. When creating section names, use the following extensions:

- `.txt` for code: for example, `.sdram.txt`
- `.rodata` for read-only data: for example, `.cfi_flash.rodata`
- `.rwdata` for read-write data: for example, `.ext_ram.rwdata`



For details about the use of these features, refer to the GNU compiler and assembler documentation. This documentation is installed with the Nios II EDS. To find it, open the Nios II EDS documentation launchpad, scroll down to **Software Development**, and click **Using the GNU Compiler Collection (GCC)**.



A powerful way to manipulate the linker memory map is by using the Nios II BSP Editor. With the BSP Editor, you can assign linker sections to specific physical regions, and then review a graphical representation of memory showing unused or overlapping regions. You start the BSP Editor from the Nios II Command Shell. For details about using the BSP Editor, refer to the editor's tool tips.

## Placement of the Heap and Stack

By default, the heap and stack are placed in the same memory partition as the `.rdata` section. The stack grows downwards (toward lower addresses) from the end of the section. The heap grows upwards from the last used memory in the `.rdata` section. You can control the placement of the heap and stack by manipulating BSP settings.

By default, the HAL performs no stack or heap checking. This makes function calls and memory allocation faster, but it means that `malloc()` (in C) and `new` (in C++) are unable to detect heap exhaustion. You can enable run-time stack checking by manipulating BSP settings. With stack checking on, `malloc()` and `new()` can detect heap exhaustion.

To specify the heap size limit, set the preprocessor symbol `ALT_MAX_HEAP_BYTES` to the maximum heap size in decimal. For example, the preprocessor argument `-DALT_MAX_HEAP_SIZE=1048576` sets the heap size limit to 0x100000. You can specify this command-line option through a BSP setting. For more information about manipulating BSP settings, refer to “HAL BSP Settings” on page 6-2.

Stack checking has performance costs. If you choose to leave stack checking turned off, you must code your program so as to ensure that it operates within the limits of available heap and stack memory.



Refer to the *Nios II Software Build Tools* chapter of the *Nios II Software Developer's Handbook* for details about selecting stack and heap placement, and setting up stack checking.

For details about how to control BSP settings, refer to “HAL BSP Settings” on page 6-2.

## Global Pointer Register

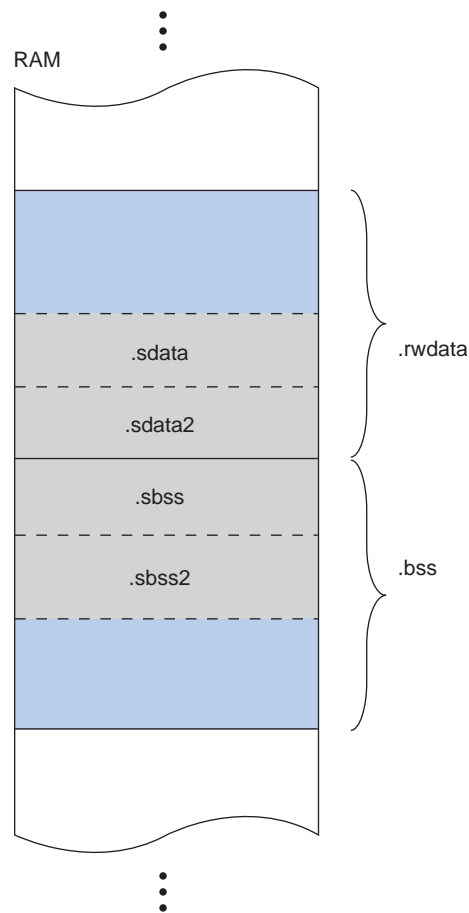
The global pointer register enables fast access to global data structures in Nios II programs. The Nios II compiler implements the global pointer, and determines which data structures to access with it. You do not need to do anything unless you want to change the default compiler behavior.

The global pointer register can access a single contiguous region of 64 Kbytes. To avoid overflowing this region, the compiler only uses the global pointer with small global data structures. A data structure is considered “small” if its size is less than a specified threshold. By default, this threshold is 8 bytes.

The small data structures are allocated to the small global data sections, `.sdata`, `.sdata2`, `.sbss`, and `.sbss2`. The small global data sections are subsections of the `.rdata` and `.bss` sections. They are located together, as shown in Figure 6-4, to enable the global pointer to access them.



**Figure 6-4.** Small Global Data sections



If the total size of the small global data structures is more than 64 Kbytes, these data structures overflow the global pointer region. The linker produces an error message saying "Unable to reach <variable name> ... from the global pointer ... because the offset ... is out of the allowed range, -32768 to 32767."

You can fix this with the `-G` compiler option. This option sets the threshold size. For example, `-G 4` restricts global pointer usage to data structures 4 bytes long or smaller. Reducing the global pointer threshold reduces the size of the small global data sections.

The `-G` option's numeric argument is in decimal. You can specify this compiler option through a project setting. For information about manipulating project settings, refer to "HAL BSP Settings" on page 6-2.



You must set this option to the same value for both the BSP and the application project.

## Boot Modes

The processor's boot memory is the memory that contains the reset vector. This device might be an external flash or an Altera EPCS serial configuration device, or it might be an on-chip RAM. Regardless of the nature of the boot memory, HAL-based systems are constructed so that all program and data sections are initially stored in it. The HAL provides a small boot loader program that copies these sections to their run time locations at boot time. You can specify run time locations for program and data memory by manipulating BSP settings.

If the runtime location of the `.text` section is outside of the boot memory, the Altera flash programmer places a boot loader at the reset address. This boot loader is responsible for loading all program and data sections before the call to `_start`. When booting from an EPCS device, this loader function is provided by the hardware.

However, if the runtime location of the `.text` section is in the boot memory, the system does not need a separate loader. Instead the `_reset` entry point in the HAL executable program is called directly. The function `_reset` initializes the instruction cache and then calls `_start`. This initialization sequence lets you develop applications that boot and execute directly from flash memory.

When running in this mode, the HAL executable program must take responsibility for loading any sections that require loading to RAM. The `.rdata`, `.rodata`, and `.exceptions` sections are loaded before the call to `alt_main()`, as required. This loading is performed by the function `alt_load()`. To load any additional sections, use the `alt_load_section()` function.



For more information about `alt_load_section()`, refer to the [HAL API Reference](#) chapter of the *Nios II Software Developer's Handbook*.

## Working with HAL Source Files

You might wish to view files in the HAL, especially header files, for reference. This section describes how to find and use HAL source files.

### Finding HAL Files

You determine the location of HAL source files when you create the BSP. HAL source files (and other BSP files) are copied to the BSP directory.



For details, refer to the [Nios II Software Build Tools Reference](#) chapter of the *Nios II Software Developer's Handbook*.

### Overriding HAL Functions

HAL source files are copied to your BSP directory when you create your BSP. If you regenerate a BSP, any HAL source files that differ from the installation files are copied. Avoid modifying BSP files. To override default HAL code, use BSP settings, or custom device drivers or software packages.



For information about what happens when you regenerate a BSP, refer to "Revising your BSP" in the [Nios II Software Build Tools](#) chapter of the *Nios II Software Developer's Handbook*.



Avoid modifying HAL source files. If you modify a HAL source file, you cannot regenerate the BSP without losing your changes. This makes it difficult to keep the BSP coordinated with changes to the underlying SOPC Builder system.



For more information, refer to “Nios II Software Projects” in the *Nios II Software Build Tools* chapter of the *Nios II Software Developer's Handbook*.

## Referenced Documents

This chapter references the following documents:

- *Getting Started with the Graphical User Interface* chapter of the *Nios II Software Developer's Handbook*
- *Getting Started from the Command Line* chapter of the *Nios II Software Developer's Handbook*
- *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*
- *Cache and Tightly-Coupled Memory* chapter of the *Nios II Software Developer's Handbook*
- *Read-Only Zip File System* 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*
- *Off-Chip Interface Peripherals* section in *Volume 5: Embedded Peripherals* of the *Quartus II Handbook*
- *The C Programming Language, Second Edition*, by Brian Kernighan and Dennis M. Ritchie (Prentice-Hall)
- *GNU documentation* on the Nios II EDS documentation launchpad

## Document Revision History

Table 6–10 shows the revision history for this document.

**Table 6–10.** Document Revision History

Date & Document Version	Changes Made	Summary of Changes
November 2009 v9.1.0	<ul style="list-style-type: none"> <li>Described <code>alt_irq_init()</code> function</li> <li>Inserted host-based file system description</li> <li>Removed IDE-specific information</li> <li>Updated information about overriding HAL functions</li> </ul>	<ul style="list-style-type: none"> <li>Introduced external interrupt controller</li> <li>BSP generation file-copy behavior changed</li> </ul>
March 2009 v9.0.0	<ul style="list-style-type: none"> <li>Reorganized and updated information and terminology to clarify role of Nios II Software Build Tools.</li> <li>Add documentation for Altera logging.</li> <li>Corrected minor typographical errors.</li> </ul>	Altera logging
May 2008 v8.0.0	No change from previous release.	
October 2007 v7.2.0	<ul style="list-style-type: none"> <li>Added documentation for HAL program development with the Nios II Software Build Tools.</li> <li>Additional documentation of alarms functions</li> <li>Correct <code>alt_erase_flash_block()</code> example</li> </ul>	—
May 2007 v7.1.0	<ul style="list-style-type: none"> <li>Added table of contents to “Introduction” section.</li> <li>Added Referenced Documents section.</li> </ul>	—
March 2007 v7.0.0	No change from previous release.	
November 2006 v6.1.0	<ul style="list-style-type: none"> <li><b>Program never exits</b> system library option</li> <li><b>Support C++</b> system library option</li> <li><b>Lightweight device driver API</b> system library option</li> <li>Minimal character-mode API</li> </ul>	
May 2006 v6.0.0	<ul style="list-style-type: none"> <li>Revised text on instruction emulation.</li> <li>Added section on global pointers.</li> </ul>	
October 2005 v5.1.0	<ul style="list-style-type: none"> <li>Added <code>alt_64</code> and <code>alt_u64</code> types to <a href="#">Table 6–1 on page 6–5</a>.</li> <li>Made changes to section “<a href="#">Placement of the Heap and Stack</a>”.</li> </ul>	
May 2005 v5.0.0	Added <code>alt_load_section()</code> function information.	
December 2004 v1.2	<ul style="list-style-type: none"> <li>Added boot modes information.</li> <li>Amended compiler optimizations.</li> <li>Updated Reducing Code Footprint section.</li> </ul>	
September 2004 v1.1	Corrected DMA receive channels example code.	
May 2004 v1.0	Initial Release.	

## Introduction

Embedded systems typically have application-specific hardware features that require custom device drivers. This chapter describes how to develop device drivers and integrate them with the hardware abstraction layer (HAL).

This chapter also describes how to develop software packages for use with HAL board support packages (BSPs). The process of integrating a software package with the HAL is nearly identical with the process for integrating a device driver.

This chapter contains the following sections:

- “Development Flow for Creating Device Drivers” on page 7-2
- “SOPC Builder Concepts” on page 7-3
- “Accessing Hardware” on page 7-3
- “Creating Drivers for HAL Device Classes” on page 7-5
- “Creating a Custom Device Driver for the HAL” on page 7-15
- “Integrating a Device Driver in the HAL” on page 7-17
- “Reducing Code Footprint” on page 7-29
- “Namespace Allocation” on page 7-31
- “Overriding the Default Device Drivers” on page 7-32

Direct interaction with the hardware should be confined to device driver code. In general, most of your program code should be free of low-level access to the hardware. Wherever possible, use the high-level HAL application program interface (API) functions to access hardware. This makes your code more consistent and more portable to other Nios® II systems that might have different hardware configurations.

When you create a new driver, you can integrate the driver with the HAL framework at one of the following two levels:

- Integration in the HAL API
- Peripheral-specific API



As an alternative to creating a driver, you can compile the device-specific code as a user library, and link it with the application. This approach is workable if the device-specific code is independent of the BSP, and does not require any of the extra services offered by the BSP, such as the ability to add definitions to the **system.h** file.

## Integration in the HAL API

Integration in the HAL API is the preferred option for a peripheral that belongs to one of the HAL generic device model classes, such as character-mode or direct memory access (DMA) devices.



For descriptions of the HAL generic device model classes, refer to the *Overview of the Hardware Abstraction Layer* chapter of the *Nios II Software Developer's Handbook*.

For integration in the HAL API, you write device access functions as specified in this chapter, and the device becomes accessible to software through the standard HAL API. For example, if you have a new LCD screen device that displays ASCII characters, you write a character-mode device driver. With this driver in place, programs can call the familiar `printf()` function to stream characters to the LCD screen.

## Peripheral-Specific API

If the peripheral does not belong to one of the HAL generic device model classes, you need to provide a device driver with an interface that is specific to the hardware implementation. In this case, the API to the device is separate from the HAL API. Programs access the hardware by calling the functions you provide, not the HAL API.

The up-front effort to implement integration in the HAL API is higher, but you gain the benefit of the HAL and C standard library API to manipulate devices.

For details about integration in the HAL API, refer to “*Integrating a Device Driver in the HAL*” on page 7–17.

All the other sections in this chapter apply to integrating drivers in the HAL API and creating drivers with a peripheral-specific API.



Although C++ is supported for programs based on the HAL, HAL drivers should not be written in C++. Restrict your driver code to either C or assembly language. C is preferred for portability.

## Before You Begin

This chapter assumes that you are familiar with C programming for the HAL.



Refer to the *Developing Programs Using the Hardware Abstraction Layer* chapter of the *Nios II Software Developer's Handbook* for information you need before reading this chapter.



This chapter uses the variable `<Altera installation>` to represent the location where the Altera® Complete Design Suite is installed. On a Windows system, by default, that location is `c:/altera/<version number>`.

## Development Flow for Creating Device Drivers

The steps to develop a new driver for the HAL depend on your device details. However, the following generic steps apply to all device classes.

1. Create the device header file that describes the registers. This header file might be the only interface required.
2. Implement the driver functionality.
3. Test from `main()`.

4. Proceed to the final integration of the driver in the HAL environment.
5. Integrate the device driver in the HAL framework.

## SOPC Builder Concepts

This section discusses basic concepts of the Altera SOPC Builder hardware design tool that enhance your understanding of the driver development process. You can develop Nios II device drivers without using SOPC Builder.

### The Relationship between `system.h` and SOPC Builder

The `system.h` header file provides a complete software description of the Nios II system hardware, and is a fundamental part of developing drivers. Because drivers interact with hardware at the lowest level, it is worth mentioning the relationship between `system.h` and SOPC Builder that generates the Nios II processor system hardware. Hardware designers use SOPC Builder to specify the architecture of the Nios II processor system and integrate the necessary peripherals and memory. Therefore, the definitions in `system.h`, such as the name and configuration of each peripheral, are a direct reflection of design choices made in SOPC Builder.



For more information about the `system.h` header file, refer to the *Developing Programs Using the Hardware Abstraction Layer* chapter of the *Nios II Software Developer's Handbook*.

### Using SOPC Builder for Optimal Hardware Configuration

If you find less-than-optimal definitions in `system.h`, remember that you can modify the contents of `system.h` by changing the underlying hardware with SOPC Builder. Before you write a device driver to accommodate imperfect hardware, it is worth considering whether the hardware can be improved easily with SOPC Builder.

### Components, Devices, and Peripherals

SOPC Builder uses the term “component” to describe hardware modules included in the system. In the context of Nios II software development, SOPC Builder components are devices, such as peripherals or memories. In the following sections, “component” is used interchangeably with “device” and “peripheral” when the context is closely related to SOPC Builder.

## Accessing Hardware

Software accesses the hardware with macros that abstract the memory-mapped interface to the device. This section describes the macros that define the hardware interface for each device.

All SOPC Builder components provide a directory that defines the device hardware and software. For example, each component provided in the Quartus® II software has its own directory in the `<Altera installation>/ip/altera/sopc_builder_ip` directory. Many components provide a header file that defines their hardware interface. The header file is named `<component name>_regs.h`, included in the `inc` subdirectory for the specific component. For example, the Altera-provided JTAG UART component defines its hardware interface in the file `<Altera installation>/ip/altera/sopc_builder_ip/altera_avalon_jtag_uart/inc/altera_avalon_jtag_uart_regs.h`.

The `_regs.h` header file defines the following access macros for the component:

- Register access macros that provide a read and/or write macro for each register in the component that supports the operation. The macros are:

- `IORD_<component name>_<register name>`  
`(<component base address>)`
- `IOWR_<component name>_<register name>`  
`(<component base address>, <data>)`

For example, `altera_avalon_jtag_uart_regs.h` defines the following macros:

- `IORD_ALTERA_AVALON_JTAG_UART_DATA( )`
- `IOWR_ALTERA_AVALON_JTAG_UART_DATA( )`
- `IORD_ALTERA_AVALON_JTAG_UART_CONTROL( )`
- `IOWR_ALTERA_AVALON_JTAG_UART_CONTROL( )`

- Register address macros that return the physical address for each register in a component. The address register returned is the component's base address + the specified register offset value. These macros are named `IOADDR_<component name>_<register name>` (`<component base address>`).

For example, `altera_avalon_jtag_uart_regs.h` defines the following macros:

- `IOADDR_ALTERA_AVALON_JTAG_UART_DATA( )`
- `IOADDR_ALTERA_AVALON_JTAG_UART_CONTROL( )`

Use these macros only as parameters to a function that requires the specific address of a data source or destination. For example, a routine that reads a stream of data from a particular source register in a component might require the physical address of the register as a parameter.

- Bit-field masks and offsets that provide access to individual bit-fields in a register. These macros have the following names:

- `<component name>_<register name>_<name of field>_MSK`—A bit-mask of the field
- `<component name>_<register name>_<name of field>_OFST`—The bit offset of the start of the field

For example, `ALTERA_AVALON_UART_STATUS_PE_MSK` and `ALTERA_AVALON_UART_STATUS_PE_OFST` access the `pe` field of the status register.



Access a device's registers only with the macros defined in the `_regs.h` file. You must use the register access functions to ensure that the processor bypasses the data cache when reading and or writing the device. Do not use hard-coded constants, because they make your software susceptible to changes in the underlying hardware.

If you are writing the driver for a completely new hardware device, you must prepare the `_regs.h` header file.



For detailed information about developing device drivers for HAL BSPs, refer to [AN 459: Guidelines for Developing a Nios II HAL Device Driver](#). For a complete example of the `_regs.h` file, refer to the component directory for any of the Altera-supplied SOPC Builder components, such as `<Altera installation>/ip/sopc_builder_ip/altera_avalon_jtag_uart/inc`. For more information about the effects of cache management and device access, refer to the [Cache and Tightly-Coupled Memory](#) chapter of the *Nios II Software Developer's Handbook*.

## Creating Drivers for HAL Device Classes

The HAL supports a number of generic device model classes. By writing a device driver as described in this section, you describe to the HAL an instance of a specific device that falls into one of its known device classes. This section defines a consistent interface for driver functions so that the HAL can access the driver functions uniformly.



Generic device model classes are defined in the [Overview of the Hardware Abstraction Layer](#) chapter of the *Nios II Software Developer's Handbook*.

The following sections define the API for the following classes of devices:

- Character-mode devices
- File subsystems
- DMA devices
- Timer devices used as system clock
- Timer devices used as timestamp clock
- Flash memory devices
- Ethernet devices

The following sections describe how to implement device drivers for each class of device, and how to register them for use in HAL-based systems.

### Character-Mode Device Drivers

This section describes how to create a device instance and register a character device.

#### Create a Device Instance

For a device to be made available as a character mode device, it must provide an instance of the `alt_dev` structure. The code in [Example 7-1](#) defines the `alt_dev` structure.

The `alt_dev` structure, defined in `<Nios II EDS install path>/components/altera_hal/HAL/inc/sys/alt_dev.h`, is essentially a collection of function pointers. These functions are called in response to application accesses to the HAL file system. For example, if you call the function `open()` with a file name that corresponds to this device, the result is a call to the `open()` function provided in this structure.

#### Example 7-1. `alt_dev` Structure

```
typedef struct {
    alt_llist    llist;      /* for internal use */
    const char*  name;
    int (*open)  (alt_fd* fd, const char* name, int flags, int mode);
    int (*close) (alt_fd* fd);
    int (*read)  (alt_fd* fd, char* ptr, int len);
    int (*write) (alt_fd* fd, const char* ptr, int len);
    int (*lseek) (alt_fd* fd, int ptr, int dir);
    int (*fstat) (alt_fd* fd, struct stat* buf);
    int (*ioctl) (alt_fd* fd, int req, void* arg);
} alt_dev;
```



For more information about `open()`, `close()`, `read()`, `write()`, `lseek()`, `fstat()`, and `ioctl()`, refer to the [HAL API Reference](#) chapter of the *Nios II Software Developer's Handbook*.

None of these functions directly modifies the global error status, `errno`. Instead, the return value is the negation of the appropriate error code provided in **`errno.h`**.

For example, the `ioctl()` function returns `-ENOTTY` if it cannot handle a request rather than set `errno` to `ENOTTY` directly. The HAL system routines that call these functions ensure that `errno` is set accordingly.

The function prototypes for these functions differ from their application level counterparts in that they each take an input file descriptor argument of type `alt_fd*` rather than `int`.

A new `alt_fd` structure is created on a call to `open()`. This structure instance is then passed as an input argument to all function calls made for the associated file descriptor.

The following code defines the `alt_fd` structure:

```
typedef struct
{
    alt_dev* dev;
    void*    priv;
    int      fd_flags;
} alt_fd;
```

where:

- `dev` is a pointer to the device structure for the device being used.
- `fd_flags` is the value of `flags` passed to `open()`.

- `priv` is a reserved, implementation-dependent argument, defined by the driver. If the driver requires any special, non-HAL-defined values to be maintained for each file or stream, you can store them in a data structure, and use `priv` maintains a pointer to the structure. The HAL ignores `priv`.

Allocate storage for the data structure in your `open()` function (pointed to by the `alt_dev` structure). Free the storage in your `close()` function.



To avoid memory leaks, ensure that the `close()` function is called when the file or stream is no longer needed.

A driver is not required to provide all of the functions in the `alt_dev` structure. If a given function pointer is set to `NULL`, a default action is used instead. Table 7-1 shows the default actions for each of the available functions.

**Table 7-1.** Default Behavior for Functions Defined in `alt_dev`

Function	Default Behavior
<code>open</code>	Calls to <code>open()</code> for this device succeed, unless the device was previously locked by a call to <code>ioctl()</code> with <code>req = TIOCEXCL</code> .
<code>close</code>	Calls to <code>close()</code> for a valid file descriptor for this device always succeed.
<code>read</code>	Calls to <code>read()</code> for this device always fail.
<code>write</code>	Calls to <code>write()</code> for this device always fail.
<code>lseek</code>	Calls to <code>lseek()</code> for this device always fail.
<code>fstat</code>	The device identifies itself as a character mode device.
<code>ioctl</code>	<code>ioctl()</code> requests that cannot be handled without reference to the device fail.

In addition to the function pointers, the `alt_dev` structure contains two other fields: `llist` and `name`. `llist` is for internal use, and should always be set to the value `ALT_LLIST_ENTRY`. `name` is the location of the device in the HAL file system and is the name of the device as defined in `system.h`.

## Register a Character Device

After you create an instance of the `alt_dev` structure, the device must be made available to the system by registering it with the HAL and by calling the following function:

```
int alt_dev_reg (alt_dev* dev)
```

This function takes a single input argument, which is the device structure to register. The return value is zero upon success. A negative return value indicates that the device cannot be registered.

After a device is registered with the HAL file system, you can access it through the HAL API and the ANSI C standard library. The node name for the device is the name specified in the `alt_dev` structure.



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

## File Subsystem Drivers

A file subsystem device driver is responsible for handling file accesses beneath a specified mount point in the global HAL file system.

### Create a Device Instance

Creating and registering a file system is very similar to creating and registering a character-mode device. To make a file system available, create an instance of the `alt_dev` structure (refer to “[Character-Mode Device Drivers](#)” on page 7-5). The only distinction is that the name field of the device represents the mount point for the file subsystem. Of course, you must also provide any necessary functions to access the file subsystem, such as `read()` and `write()`, similar to the case of the character-mode device.



If you do not provide an implementation of `fstat()`, the default behavior returns the value for a character-mode device, which is incorrect behavior for a file subsystem.

### Register a File Subsystem Device

You can register a file subsystem using the following function:

```
int alt_fs_reg (alt_dev* dev)
```

This function takes a single input argument, which is the device structure to register. A negative return value indicates that the file system cannot be registered.

After a file subsystem is registered with the HAL file system, you can access it through the HAL API and the ANSI C standard library. The mount point for the file subsystem is the name specified in the `alt_dev` structure.



For more information, refer to the [Developing Programs Using the Hardware Abstraction Layer](#) chapter of the *Nios II Software Developer's Handbook*.

## Timer Device Drivers

This section describes the system clock and timestamp drivers.

### System Clock Driver

A system clock device model requires a driver to generate the periodic clock tick. There can be only one system clock driver in a system. You implement a system clock driver as an interrupt service routine (ISR) for a timer peripheral that generates a periodic interrupt. The driver must provide periodic calls to the following function:


```
void alt_tick (void)
```

The expectation is that `alt_tick()` is called in exception context.

To register the presence of a system clock driver, call the following function:


```
int alt_sysclk_init (alt_u32 nticks)
```

The input argument `nticks` is the number of system clock ticks per second, which is determined by your system clock driver. The return value of this function is zero on success, and nonzero otherwise.

 For more information about writing interrupt service routines, refer to the *Exception Handling* chapter of the *Nios II Software Developer's Handbook*.

### Timestamp Driver

A timestamp driver provides implementations for the three timestamp functions: `alt_timestamp_start()`, `alt_timestamp()`, and `alt_timestamp_freq()`. The system can only have one timestamp driver.

 For more information about using these functions, refer to the *Developing Programs Using the Hardware Abstraction Layer* and *HAL API Reference* chapters of the *Nios II Software Developer's Handbook*.

## Flash Device Drivers

This section describes how to create a flash driver and register a flash device.

### Create a Flash Driver

Flash device drivers must provide an instance of the `alt_flash_dev` structure, defined in `sys/alt_flash_dev.h`. The following code shows the structure:

```
struct alt_flash_dev
{
    alt_llist                llist; // internal use only
    const char*              name;
    alt_flash_open           open;
    alt_flash_close          close;
    alt_flash_write          write;
    alt_flash_read           read;
    alt_flash_get_flash_info get_info;
    alt_flash_erase_block    erase_block;
    alt_flash_write_block    write_block;
    void*                    base_addr;
    int                      length;
    int                      number_of_regions;
    flash_region             region_info[ALT_MAX_NUMBER_OF_FLASH_REGIONS];
};
```

The first parameter `llist` is for internal use, and should always be set to the value `ALT_LLIST_ENTRY`. `name` is the location of the device in the HAL file system and is the name of the device as defined in `system.h`.

The seven fields `open` to `write_block` are function pointers that implement the functionality behind the application API calls to the following functions:

- `alt_flash_open_dev()`
- `alt_flash_close_dev()`
- `alt_write_flash()`
- `alt_read_flash()`
- `alt_get_flash_info()`
- `alt_erase_flash_block()`
- `alt_write_flash_block()`

where:

- the `base_addr` parameter is the base address of the flash memory
- `length` is the size of the flash in bytes
- `number_of_regions` is the number of erase regions in the flash
- `region_info` contains information about the location and size of the blocks in the flash device



For more information about the format of the `flash_region` structure, refer to “Using Flash Devices” in the *Developing Programs Using the Hardware Abstraction Layer* chapter of the *Nios II Software Developer’s Handbook*.

Some flash devices, such as common flash interface (CFI)-compliant devices, allow you to read out the number of regions and their configuration at run time. For all other flash devices, these two fields must be defined at compile time.

### Register a Flash Device

After creating an instance of the `alt_flash_dev` structure, you must make the device available to the HAL system by calling the following function:

```
int alt_flash_device_register( alt_flash_fd* fd)
```

This function takes a single input argument, which is the device structure to register. The return value is zero upon success. A negative return value indicates that the device cannot be registered.

## DMA Device Drivers

The HAL models a DMA transaction as being controlled by two endpoint devices: a receive channel and a transmit channel. This section describes the drivers for each type of DMA channel separately.



For a complete description of the HAL DMA device model, refer to “Using DMA Devices” the *Developing Programs Using the Hardware Abstraction Layer* chapter of the *Nios II Software Developer’s Handbook*.

The DMA device driver interface is defined in `sys/alt_dma_dev.h`.

### DMA Transmit Channel

A DMA transmit channel is constructed by creating an instance of the `alt_dma_txchan` structure, shown in [Example 7-2](#).

### Example 7-2. alt\_dma\_txchan Structure

```
typedef struct alt_dma_txchan_dev_s alt_dma_txchan_dev;
struct alt_dma_txchan_dev_s
{
    alt_llist    llist;
    const char*  name;
    int          (*space) (alt_dma_txchan dma);
    int          (*send) (alt_dma_txchan dma,
                        const void*      from,
                        alt_u32          len,
                        alt_txchan_done* done,
                        void*            handle);
    int          (*ioctl) (alt_dma_txchan dma, int req, void* arg);
};
```

Table 7-2 shows the available fields and their functions.

Both the space and send functions need to be defined. If the ioctl field is set to null, calls to alt\_dma\_txchan\_ioctl() return -ENOTTY for this device.

After creating an instance of the alt\_dma\_txchan structure, you must register the device with the HAL system to make it available by calling the following function:

```
int alt_dma_txchan_reg (alt_dma_txchan_dev* dev)
```

**Table 7-2.** Fields in the alt\_dma\_txchan Structure

Field	Function
llist	This field is for internal use, and must always be set to the value ALT_LLIST_ENTRY.
name	The name that refers to this channel in calls to alt_dma_txchan_open(). name is the name of the device as defined in <b>system.h</b> .
space	A pointer to a function that returns the number of additional transmit requests that can be queued to the device. The input argument is a pointer to the alt_dma_txchan_dev structure.
send	A pointer to a function that is called as a result of a call to the application API function alt_dma_txchan_send(). This function posts a transmit request to the DMA device. The parameters passed to alt_txchan_send() are passed directly to send(). For a description of parameters and return values, refer to the <i>HAL API Reference</i> chapter of the <i>Nios II Software Developer's Handbook</i> .
ioctl	This function provides device specific I/O control. Refer to <b>sys/alt_dma_dev.h</b> for a list of the generic options that you might want your device to support.

The input argument dev is the device to register. The return value is zero on success, or negative if the device cannot be registered.

### DMA Receive Channel

A DMA receive channel is constructed by creating an instance of the alt\_dma\_rxchan structure, shown in [Example 7-3](#).

**Example 7-3.** alt\_dma\_rxchan Structure

```

typedef alt_dma_rxchan_dev_s alt_dma_rxchan;
struct alt_dma_rxchan_dev_s
{
    alt_llist    list;
    const char* name;
    alt_u32      depth;
    int          (*prepare) (alt_dma_rxchan dma,
                           void* data,
                           alt_u32 len,
                           alt_rxchan_done* done,
                           void* handle);
    int          (*ioctl) (alt_dma_rxchan dma, int req, void* arg);
};

```

Table 7-3 shows the available fields and their functions.

The `prepare()` function must be defined. If the `ioctl` field is set to null, calls to `alt_dma_rxchan_ioctl()` return `-ENOTTY` for this device.

After creating an instance of the `alt_dma_rxchan` structure, you must register the device driver with the HAL system to make it available by calling the following function:

```
int alt_dma_rxchan_reg (alt_dma_rxchan_dev* dev)
```

The input argument `dev` is the device to register. The return value is zero on success, or negative if the device cannot be registered.

**Table 7-3.** Fields in the alt\_dma\_rxchan Structure

Field	Function
l1ist	This function is for internal use and should always be set to the value <code>ALT_LLIST_ENTRY</code> .
name	The name that refers to this channel in calls to <code>alt_dma_rxchan_open()</code> . <code>name</code> is the name of the device as defined in <b>system.h</b> .
depth	The total number of receive requests that can be outstanding at any given time.
prepare	A pointer to a function that is called as a result of a call to the application API function <code>alt_dma_rxchan_prepare()</code> . This function posts a receive request to the DMA device. The parameters passed to <code>alt_dma_rxchan_prepare()</code> are passed directly to <code>prepare()</code> . For a description of parameters and return values, refer to the <i>HAL API Reference</i> chapter of the <i>Nios II Software Developer's Handbook</i> .
ioctl	This is a function that provides device specific I/O control. Refer to <b>sys/alt_dma_dev.h</b> for a list of the generic options that a device might wish to support.

## Ethernet Device Drivers

The HAL generic device model for Ethernet devices provides access to the NicheStack® TCP/IP Stack - Nios II Edition running on the MicroC/OS-II operating system. You can provide support for a new Ethernet device by supplying the driver functions that this section defines.

Before you consider writing a device driver for a new Ethernet device, you need a basic understanding of the Altera implementation of the NicheStack TCP/IP Stack and its usages.




 For more information, refer to the *Ethernet and the NicheStack TCP/IP Stack - Nios II Edition* chapter of the *Nios II Software Developer's Handbook*.

The easiest way to write a new Ethernet device driver is to start with Altera's implementation for the SMSC lan91c111 device, and modify it to suit your Ethernet media access controller (MAC). This section assumes you take this approach. Starting from a known working example makes it easier for you to learn the most important details of the NicheStack TCP/IP Stack implementation.

The source code for the lan91c111 driver is provided with the Quartus II software in `<Altera installation>/ip/altera/sopc_builder_ip/altera_avalon_lan91c111/UCOSII`. For the sake of brevity, this section refers to this directory as `<SMSC path>`. The source files are in the `<SMSC path>/src/iniche` and `<SMSC path>/inc/iniche` directories.

A number of useful NicheStack TCP/IP Stack files are installed with the Nios II Embedded Design Suite (EDS), under the `<Nios II EDS install path>/components/altera_iniche/UCOSII` directory. For the sake of brevity, this chapter refers to this directory as `<iniche path>`.

 For more information about the NicheStack TCP/IP Stack implementation, refer to the *NicheStack Technical Reference Manual*, available on the [Literature: Nios II Processor](#) page of the Altera website.

You need not edit the NicheStack TCP/IP Stack source code to implement a NicheStack-compatible driver. Nevertheless, Altera provides the source code for your reference. The files are installed with the Nios II EDS in the `<iniche path>` directory. The Ethernet device driver interface is defined in `<iniche path>/inc/alt_iniche_dev.h`.

The following sections describe how to provide a driver for a new Ethernet device.

### Provide the NicheStack Hardware Interface Routines

The NicheStack TCP/IP Stack architecture requires several network hardware interface routines:

- Initialize hardware
- Send packet
- Receive packet
- Close
- Dump statistics

These routines are fully documented in the *Porting Engineer Provided Functions* chapter of the *NicheStack Technical Reference*. The corresponding functions in the SMSC lan91c111 device driver are shown in [Table 7-4](#).

**Table 7-4.** SMSC lan91c111 Hardware Interface Routines

Prototype function	lan91c111 function	File	Notes
n_init()	s91_init()	smc91x.c	The initialization routine can install an ISR if applicable
pkt_send()	s91_pkt_send()	smc91x.c	
Packet receive mechanism	s91_isr()	smc91x.c	Packet receive includes three key actions: <ul style="list-style-type: none"> <li>■ pk_alloc()—Allocate a netbuf structure</li> <li>■ putq()—Place netbuf structure on rcvdq</li> <li>■ SignalPktDemux()—Notify the Internet protocol (IP) layer that it can demux the packet</li> </ul>
	s91_rcv()	smc91x.c	
	s91_dma_rx_done()	smc_mem.c	
n_close()	s91_close()	smc91x.c	
n_stats()	s91_stats()	smc91x.c	

The NicheStack TCP/IP Stack system code uses the net structure internally to define its interface to device drivers. The net structure is defined in **net.h**, in *<niche path>/src/downloads/30src/h*. Among other things, the net structure contains the following things:

- A field for the IP address of the interface
- A function pointer to a low-level function to initialize the MAC device
- Function pointers to low-level functions to send packets

Typical NicheStack code refers to type NET, which is defined as \*net.

### Provide \*INSTANCE and \*INIT Macros

To enable the HAL to use your driver, you must provide two HAL macros. The names of these macros are based on the name of your network interface component, according to the following templates:

- *<component name>\_INSTANCE*
- *<component name>\_INIT*

For examples, refer to ALTERA\_AVALON\_LAN91C111\_INSTANCE and ALTERA\_AVALON\_LAN91C111\_INIT in *<SMSC path>/inc/niche/altera\_avalon\_lan91c111\_iniche.h*, which is included in *<niche path>/inc/altera\_avalon\_lan91c111.h*.

You can copy **altera\_avalon\_lan91c111\_iniche.h** and modify it for your own driver. The HAL expects to find the \*INIT and \*INSTANCE macros in *<component name>.h*, as discussed in “[Header Files and alt\\_sys\\_init.c](#)” on [page 7-16](#). You can accomplish this with a #include directive as in **altera\_avalon\_lan91c111.h**, or you can define the macros directly in *<component name>.h*.

Your `*INSTANCE` macro declares data structures required by an instance of the MAC. These data structures must include an `alt_iniche_dev` structure. The `*INSTANCE` macro must initialize the first three fields of the `alt_iniche_dev` structure, as follows:

- The first field, `llist`, is for internal use, and must always be set to the value `ALT_LLIST_ENTRY`.
- The second field, `name`, must be set to the device name as defined in `system.h`. For example, `altera_avalon_lan91c111_iniche.h` uses the C preprocessor's `##` (concatenation) operator to reference the `LAN91C111_NAME` symbol defined in `system.h`.
- The third field, `init_func`, must point to your software initialization function, as described in “Provide a Software Initialization Function”. For example, `altera_avalon_lan91c111_iniche.h` inserts a pointer to `alt_avalon_lan91c111_init()`.

Your `*INIT` macro initializes the driver software. Initialization must include a call to the `alt_iniche_dev_reg()` macro, defined in `alt_iniche_dev.h`. This macro registers the device with the HAL by adding the driver instance to `alt_iniche_dev_list`.

When your driver is included in a Nios II BSP project, the HAL automatically initializes your driver by invoking the `*INSTANCE` and `*INIT` macros from its `alt_sys_init()` function. Refer to “Header Files and `alt_sys_init.c`” on page 7-16 for further detail about the `*INSTANCE` and `*INIT` macros.

### Provide a Software Initialization Function

The `*INSTANCE()` macro inserts a pointer to your initialization function in the `alt_iniche_dev` structure, as described in “Provide `*INSTANCE` and `*INIT` Macros” on page 7-14. Your software initialization function must perform at least the following three tasks:

- Initialize the hardware and verify its readiness
- Finish initializing the `alt_iniche_dev` structure
- Call `get_mac_addr()`

The initialization function must perform any other initialization your driver needs, such as creation and initialization of custom data structures and ISRs.



For details about the `get_mac_addr()` function, refer to the *Ethernet and the NicheStack TCP/IP Stack - Nios II Edition* chapter of the *Nios II Software Developer's Handbook*.

For an example of a software initialization function, refer to `alt_avalon_lan91c111_init()` in `<SMSC path>/src/iniche/smsc91x.c`.

## Creating a Custom Device Driver for the HAL

This section describes how to provide appropriate files to integrate your device driver in the HAL. The “Integrating a Device Driver in the HAL” section on page 7-17 describes the correct locations for the files.

## Header Files and alt\_sys\_init.c

At the heart of the HAL is the autogenerated source file, **alt\_sys\_init.c**. This file contains the source code that the HAL uses to initialize the device drivers for all supported devices in the system. In particular, this file defines the `alt_sys_init()` function, which is called before `main()` to initialize device drivers software packages, and make them available to the program.

When you create the driver or software package, you specify in a Tcl script whether you want the `alt_sys_init()` function to invoke your `INSTANCE` and `INIT` macros. Refer to “[Enabling Software Initialization](#)” on page 7-24 for details.

**Example 7-4** shows excerpts from an **alt\_sys\_init.c** file.



The remainder of this section assumes that you are using the `alt_sys_init()` HAL initialization mechanism.

The Software Build Tools create **alt\_sys\_init.c** based on the header files associated with each device driver and software package. For a device driver, the header file must define the macros `<component name>_INSTANCE` and `<component name>_INIT`.

Like a device driver, a software package provides an `INSTANCE` macro, which `alt_sys_init()` invokes once. A software package header file can optionally provide an `INIT` macro.

### **Example 7-4.** Excerpt from an alt\_sys\_init.c File Performing Driver Initialization

---

```
#include "system.h"
#include "sys/alt_sys_init.h"

/*
 * device headers
 */
#include "altera_avalon_timer.h"
#include "altera_avalon_uart.h"

/*
 * Allocate the device storage
 */
ALTERA_AVALON_UART_INSTANCE( UART1, uart1 );
ALTERA_AVALON_TIMER_INSTANCE( SYSCLK, sysclk );

/*
 * Initialize the devices
 */
void alt_sys_init( void )
{
    ALTERA_AVALON_UART_INIT( UART1, uart1 );
    ALTERA_AVALON_TIMER_INIT( SYSCLK, sysclk );
}
```

---

For example, `altera_avalon_jtag_uart.h` must define the macros `ALTERA_AVALON_JTAG_UART_INSTANCE` and `ALTERA_AVALON_JTAG_UART_INIT`. The purpose of these macros is as follows:

- The `*_INSTANCE` macro performs any required static memory allocation. For drivers, `*_INSTANCE` is invoked once per device instance, so that memory can be initialized on a per-device basis. For software packages, `*_INSTANCE` is invoked once.
- The `*_INIT` macro performs runtime initialization of the device driver or software package.

In the case of a device driver, both macros take two input arguments:

- The first argument, `name`, is the capitalized name of the device instance.
- The second argument, `dev`, is the lower case version of the device name. `dev` is the name given to the component in SOPC Builder at system generation time.

You can use these input parameters to extract device-specific configuration information from the `system.h` file.

The name of the header file must be as follows:

- Device driver: `<hardware component class>.h`. For example, if your driver targets the `altera_avalon_uart` component, the file name is `altera_avalon_uart.h`.
- Software packages `<package name>.h`. For example, if you create the software package with the following command:

```
create_sw_package my_sw_package
```

the header file is called `my_sw_package.h`.



For a complete example, refer to any of the Altera-supplied device drivers, such as the JTAG UART driver in `<Altera installation>/ip/sopc_builder_ip/altera_avalon_jtag_uart`.



For optimal project rebuild time, do not include the peripheral header in `system.h`. It is included in `alt_sys_init.c`.

## Device Driver Source Code

In addition to the header file, the component driver might need to provide compilable source code, to be incorporated in the BSP. This source code is specific to the hardware component, and resides in one or more C files (or assembly language files).

## Integrating a Device Driver in the HAL

The Nios II Software Build Tools can incorporate device drivers and software packages supplied by Altera, supplied by other third-party developers, or created by you. This section describes how to prepare device drivers and software packages so the BSP generator recognizes and adds them to a generated BSP.

You can take advantage of this service, whether you created a device driver for one of the HAL generic device models, or you created a peripheral-specific device driver.



The process required to integrate a device driver is nearly identical to that required to develop a software package. The following sections describe the process for both. Certain steps are not needed for software packages, as noted in the text.

## Overview

To publish a device driver or a software package, you provide the following items:

- A header file defining the package or driver interface
- A Tcl script specifying how to add the package or driver to a BSP

The header file and Tcl script are described in the following sections.

## Assumptions and Requirements

This section assumes that you are developing a device driver or software package for eventual incorporation in a BSP. The driver or package is to be incorporated in the BSP by an end user who has limited knowledge of the driver or package internal implementation. To add your driver or package to a BSP, the end user must rely on the driver or package settings that you create with the tools described in this section.

For a device driver or software package to work with the Nios II Software Build Tools, it must meet the following criteria:

- It must have a defining Tcl script. The Tcl script for each driver or software package provides the Nios II Software Build Tools with a complete description of the driver or software. This description includes the following information:
  - Name—A unique name identifying the driver or software package
  - Source files—The location, name, and type of each C/C++ or assembly language source or header file
  - Associated hardware class (device drivers only)—The name of the hardware peripheral class the driver supports
  - Version and compatibility information—The driver or package version, and (for drivers) information about what device core versions it supports.
  - BSP type(s)—The supported operating system(s)
  - Settings—The visible parameters controlling software build and runtime configuration
- The Tcl script resides in the driver or software package root directory.
- The Tcl script's file name ends with **\_sw.tcl**. Example: **custom\_ip\_block\_sw.tcl**.
- The root directory of the driver or software package is in one of the following places:
  - In any directory included in the `SOPC_BUILDER_PATH` environment variable, or in any directory located one level beneath such a directory. This approach is recommended if your driver or software packages are installed in a distribution you create.
  - In a directory named **ip**, one level beneath the Quartus II project directory containing the design your BSP targets. This approach is recommended if your driver or software package is used only once, in a specific hardware project.

- File names and directory structures conform to certain conventions, described in “[File Names and Locations](#)” on page 7-20.
- If your driver or software package uses the HAL autoinitialization mechanism (`alt_sys_init()`), certain macros must be defined in a header file. For details about this header file, refer to “[Header Files and alt\\_sys\\_init.c](#)” on page 7-16.



The *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook* describes the commands you can use in the Tcl script.

## The Nios II BSP Generator

This section describes the process by which the Nios II BSP generator adds device drivers and software packages to your BSP. The Nios II BSP generator, a subset of the Nios II Software Build Tools, is a combination of command utilities and scripts that enable you to create and manage BSPs and their settings.



For an overview of the Nios II Software Build Tools, refer to the *Overview* and *Getting Started from the Command Line* chapters of the *Nios II Software Developer's Handbook*.

### Component Discovery

When you run any BSP generator utility, a library of available drivers and software packages is populated.

The BSP generator locates software packages and drivers by inspecting a list of known locations determined by the Altera Nios II EDS, Quartus II software, and MegaCore® IP Library installers, as well as searching locations specified in certain system environment variables.

The Nios II BSP tools identify drivers and software packages by locating and sourcing Tcl scripts with file names ending in `_sw.tcl` in these locations.



For run-time efficiency, the BSP generator only looks at driver files that conform to the criteria listed in this section.

After locating each driver and software package, the Nios II Software Build Tools search for a suitable driver for each hardware module in the SOPC Builder system (mastered by the Nios II processor that the BSP is generated for), as well as software packages that the BSP creator requested.

### Device Driver Versions

In the case of device drivers, the highest version of driver that is compatible with the associated hardware peripheral is added to the BSP, unless specified otherwise by the device driver management commands.



For further information, refer to the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*.

### Device Driver and Software Package Inclusion

The BSP generator adds software packages to the BSP if they are specifically requested during BSP generation, with the `enable_sw_package` command.



For further details, refer to “Tcl Commands” in the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer’s Handbook*.

If no specific device driver is requested, and no compatible device driver is located for a particular hardware module, the BSP generator issues an informative message visible in either the debug or verbose generation output. This behavior is normal for many types of hardware in the SOPC Builder system, such as memory devices, that do not have device drivers. If a software package or specific driver is requested and cannot be located, an error is generated and BSP generation or settings update halts.

Creating a Tcl script allows you to add extra definitions in the **system.h** file, enable automatic driver initialization through the **alt\_sys\_init.c** structure, and enable the Nios II Software Build Tools to control any extra parameters that might exist.

With the Tcl software definition files in place, the Software Build Tools read in the Tcl file and populate the makefiles and other support files accordingly.

When the Nios II Software Build Tools add each driver or software package to the system, they use the data in the Tcl script defining the driver or software package to control each file copied in to the BSP. This rule also affects generated BSP files such as the BSP **Makefile**, **public.mk**, **system.h**, and the BSP settings and summary HTML files.

When you create a new software project, the Nios II Software Build Tools generate the contents of **alt\_sys\_init.c** to match the specific hardware contents of the SOPC Builder system.

## File Names and Locations

As described in “The Nios II BSP Generator” on page 7-19, the Nios II build tools find a device driver or software package by locating a Tcl script with the file name ending in **\_sw.tcl**, and sourcing it.

Each peripheral in a Nios II system is associated with a specific SOPC Builder component directory. This directory contains a file defining the software interface to the peripheral. Refer to “Accessing Hardware” on page 7-3.

To enable the Software Build Tools to find your component device driver, place the Tcl script in a directory named **ip** under your hardware project directory.

Figure 7-1 illustrates a file hierarchy suitable for the Nios II Software Build Tools. This file hierarchy is located in the *<Altera installation>/ip/altera/sopc\_builder\_ip* directory. This example assumes a device driver supporting a hardware component named **custom\_component**.

### Source Code Discovery

You use Tcl scripts to specify the location of driver source files. For further details, refer to “The Nios II BSP Generator” on page 7-19.



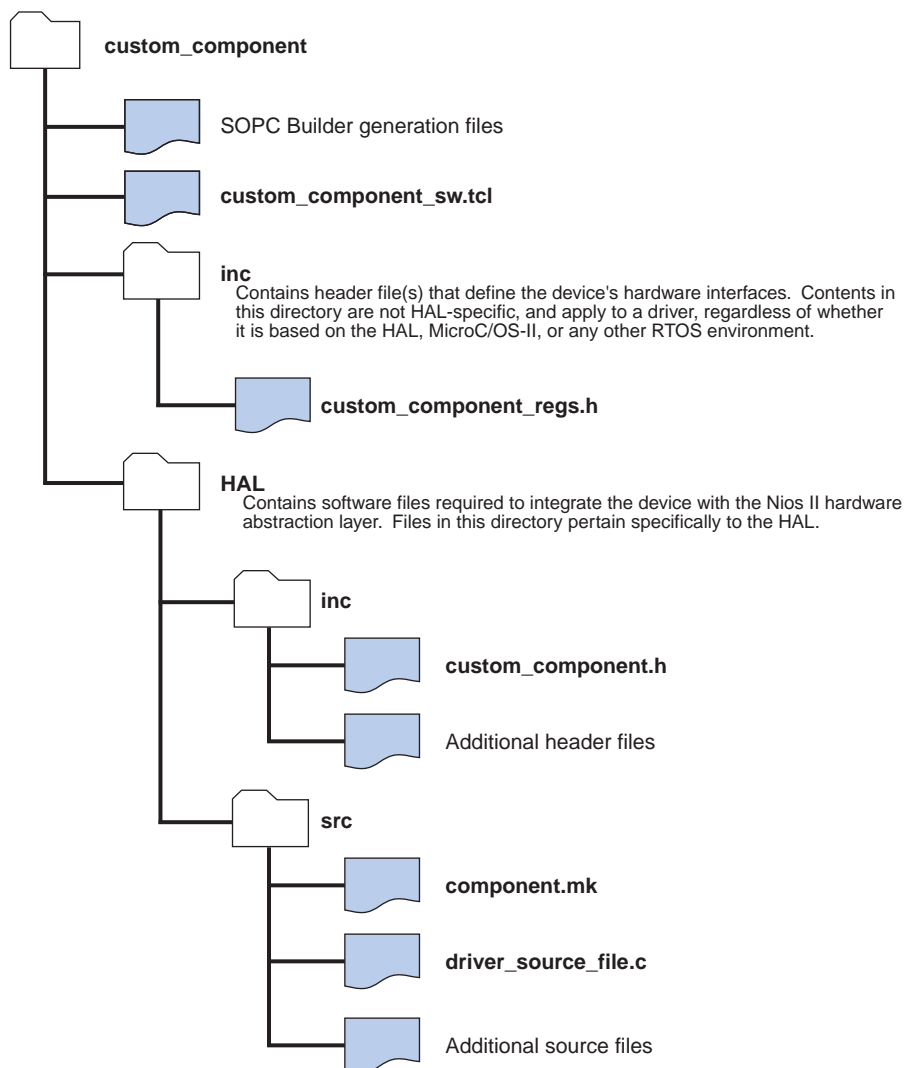
## Driver and Software Package Tcl Script Creation

This section discusses writing a Tcl script to describe your software package or driver. The exact contents of the Tcl script depends on the structure and complexity of your driver or software. For many simple device drivers, you need only include a few commands. For more complex software, the Nios II Software Build Tools provide powerful features that give the BSP end user control of your software or driver's operation.

The Tcl command and argument descriptions in this section are not exhaustive. For a detailed explanation of each command and all arguments, refer to the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*.

For a reference in creating your own driver or software Tcl files, you can also view the driver and software package Tcl scripts included with the Nios II EDS and the MegaCore IP library. These scripts are in the `<Nios II EDS install path>/components` and `<MegaCore IP library install path>/sopc_builder_ip` folders, respectively.

**Figure 7-1.** Example Device Driver File Hierarchy and Naming



## Tcl Command Walkthrough for a Typical Driver or Software Package

The Tcl script excerpts in this section describe a typical device driver or software package.

The example in this section creates a device driver for a hardware peripheral whose SOPC Builder component class name is `my_custom_component`. The driver supports both HAL and MicroC/OS-II BSP types. It has a single C source file (.c) and two C header files (.h), organized as in the example in [Figure 7-1](#).

### Creating and Naming the Driver or Package

The first command in any driver or software package Tcl script must be the `create_driver` or `create_sw_package` command. The remaining commands can be in any order. Use the appropriate **create** command only once per Tcl file. Choose a unique driver or package name. For drivers, Altera recommends appending `_driver` to the associated hardware class name. The following example illustrates this convention.

```
create_driver my_custom_component_driver
```

### Identifying the Hardware Component Class

Each driver must identify the hardware component class the driver is associated with in the `set_sw_property` command's `hw_class_name` argument. The following example associates the driver with a hardware class called `my_custom_component`:

```
set_sw_property hw_class_name my_custom_component
```



The `set_sw_property` command accepts several argument types. Each call to `set_sw_property` sets or overwrites a property to the value specified in the second argument.



For further information about the `set_sw_property` command, refer to the [Nios II Software Build Tools Reference](#) chapter of the *Nios II Software Developer's Handbook*.

The `hw_class_name` argument does not apply to software packages.

If you are creating your own driver to use in place of an existing one (for example, a custom UART driver for the `altera_avalon_uart` component), specify a driver name different from the standard driver. The Nios II Software Build Tools use your driver only if you specify it explicitly.



For further details, refer to the [Nios II Software Build Tools Reference](#) chapter of the *Nios II Software Developer's Handbook*.

Choose a name for your driver or software package that does not conflict with other Altera-supplied software or IP, or any third-party software or IP installed on your host system. The BSP generator uses the name you specify to look up the software package or driver during BSP creation. If the Nios II Software Build Tools find multiple compatible drivers or software packages with the same name, they might pick any of them.

If you intend to distribute your driver or software package, Altera recommends prefixing all names with your organization's name.

### Setting the BSP Type

You must specify each operating system (or BSP type) that your driver or software package supports. Use the `add_sw_property` command's `supported_bsp_type` argument to specify each compatible operating system. In most cases, a driver or software package supports both Altera HAL (`hal`) and Micrium MicroC/OS-II (`ucosii`) BSP types, as in the following example:

```
add_sw_property supported_bsp_type hal
add_sw_property supported_bsp_type ucosii
```



The `add_sw_property` command accepts several argument types. Each call to `add_sw_property` adds the final argument to the property specified in the second argument.



Support for additional operating system and BSP types is not present in this release of the Nios II Software Build Tools.

### Specifying an Operating System

Many drivers and software packages do not require any particular operating system. However, you can structure your software to provide different source files depending on the operating system used.

If your driver or software has different source files, paths, or settings that depend on the operating system used, write a Tcl script for each variant of the driver or software package. Each script must specify the same software package or driver name in the `create_driver` or `create_sw_package` command, and same `hw_class_name` in the case of device drivers. Each script must specify only the files, paths, and other settings that pertain to that operating system. During BSP generation, only drivers or software packages that specify compatibility with the selected operating system (OS) type are eligible to add to the BSP.

### Specifying Source Files

Using the Tcl command interface, you must specify each source file in your driver or software package that you want in the generated BSP. The commands discussed in this section add driver source files and specify their location in the file system and generated BSP.

The `add_sw_property` command's `c_source` and `asm_source` arguments add a single `.c` or Nios II assembly language source file (`.s` or `.S`) to your driver or software package. You must express path information to the source relative to the driver root (the location of the Tcl file). `add_sw_property` copies source files to BSPs that incorporate the driver, using the path information specified, and adds them to source file list in the generated BSP makefile. When you build the BSP using `make`, the driver source files are compiled as follows:

```
add_sw_property c_source HAL/src/my_driver.c
```

The `add_sw_property` command's `include_source` argument adds a single header file in the path specified to the driver. The paths are relative to the driver root. `add_sw_property` copies header files to the BSP during generation, using the path information specified at generation time. It does not include header files in the makefile.

```
add_sw_property include_source inc/my_custom_component_regs.h
add_sw_property include_source HAL/inc/my_custom_component.h
```

### Specifying a Subdirectory

You can optionally specify a subdirectory in the generated BSP for your driver or software package files using the `bsp_subdirectory` argument to `set_sw_property`. All driver source and header files are copied to this directory, along with any path or hierarchy information specified with each source or header file. If no `bsp_subdirectory` is specified, your driver or software package is placed under the **drivers** folder of the generated BSP. Set the subdirectory as follows:

```
set_sw_property bsp_subdirectory my_driver
```



If the path begins with the BSP type (e.g. HAL or UCOSII), the BSP type is removed and replaced with the value of the `bsp_subdirectory` property.

### Enabling Software Initialization

If your driver or software package uses the HAL autoinitialization mechanism, your source code includes `INSTANCE` and `INIT` macros, to create storage for each driver instance, and to call any initialization routines. The generated `alt_sys_init.c` file invokes these macros, which must be defined in a header file named `<hardware component class>.h`.

For further details, refer to “Provide `*INSTANCE` and `*INIT` Macros” on page 7–14.

To support this functionality in Nios II BSPs, you must set the `set_sw_property` command's `auto_initialize` argument to true using the following Tcl command:

```
set_sw_property auto_initialize true
```

If you do not turn on this attribute, `alt_sys_init.c` does not invoke the `INIT` and `INSTANCE` macros.

### Adding Include Paths

By default, the generated BSP **Makefile** and **public.mk** add include paths to find header files in `/inc` or `<BSP type>/inc` folders.

You might need to set up a header file directory hierarchy to logically organize your code. You can add additional include paths to your driver or software package using the `add_sw_property` command's `include_directory` argument as follows:

```
add_sw_property include_directory UCOSII/inc/protocol/h
```



If the path begins with the BSP type (e.g. HAL or UCOSII), the BSP type is removed and replaced with the value of the `bsp_subdirectory` property.

Additional include paths are added to the preprocessor flags in the BSP **public.mk** file. These preprocessor flags allow BSP source files, as well as application and user library source files that reference the BSP, to find the include path while each source file is compiled.



Adding additional include paths is not required if your source code includes header files with explicit path names. You can also specify the location of the header files with a `#include` directive similar to the following:

```
#include "protocol/h/<filename>"
```

### Version Compatibility

Your device driver or software package can optionally specify versioning information through the Tcl command interface. The driver and software package Tcl commands specifying versioning information allow the following functionality:

- You can request a specific version of your driver or software package with BSP settings.
- You can make updates to your device driver and specify that the driver is still compatible with a minimum hardware class version, or specific hardware class versions. This facility is especially useful in situations in which a hardware design is stable and you foresee making software updates over time.

The `<version>` argument in each of the following versioning-related commands can be a string containing numbers and characters. Examples of version strings are 8.0, 5.1.1, 6.1, and 6.1sp1. The `.` character is a separator. The BSP generator compares versions against each other to determine if one is more recent than the other, or if two are equal, by successively comparing the strings between each separator. Thus, 2.1 is greater than 2.0, and 2.1sp1 is greater than 2.1. Two versions are equal if their version assignment strings are identical.

Use the `version` argument of `set_sw_property` to assign a version to your driver or software package. If you do not assign a version to your software or device driver, the version of the Nios II EDS installation (containing the Nios II BSP commands being executed) is set for your driver or software package:

```
set_sw_property version 7.1
```

Device drivers (but not software packages) can use the `min_compatible_hw_version` and `specific_compatible_hw_version` arguments to establish compatibility with their associated hardware class, as follows:

```
set_sw_property min_compatible_hw_version 5.0.1add_sw_property  
specific_compatible_hw_version 6.1sp1
```

You can add multiple specific compatible versions. This functionality allows you to roll out a new version of a device driver that tracks changes supporting a hardware peripheral change.

For device drivers, if no compatible version information is specified, the version of the device driver must be equal to the associated hardware class. Thus, if you do not wish to use this feature, Altera recommends setting the `min_compatible_hw_version` of your driver to the lowest version of the associated hardware class your driver is compatible with.

### Creating Settings for Device Drivers and Software Packages

The BSP generator allows you to publish settings for individual device drivers and software packages. These settings are visible and can be modified by the BSP user, if the BSP includes your driver or software package. Use the Tcl command interface to create settings.

The Tcl command that publishes settings is especially useful if your driver or software package has build or runtime options that are normally specified with `#define` statements or makefile definitions at software build time. Settings can also add custom variable declarations to the BSP **Makefile**.

Settings affect the generated BSP in several ways:

- Settings are added either to the BSP **system.h** or **public.mk**, or to the BSP **Makefile** as variable.
- Settings are stored in the BSP settings file, named with hierarchy information to prevent namespace collision.
- A default value of your choice is assigned to the setting so that the end user of the driver or package does not need to explicitly specify the setting when creating or updating a BSP.
- Settings are displayed in the BSP **summary.html** document, along with description text of your choice.

Use the `add_sw_setting` Tcl command to add a setting. To specify the details, `add_sw_setting` requires each of the following arguments, in the order shown:

1. `type`—The data type, which controls formatting of the setting's value assignment in the appropriate generated file.
2. `destination`—The destination file in the BSP.
3. `displayName`—The name that is used to identify the setting when changing BSP settings or viewing the BSP **summary.html** document
4. `identifier`—Conceptually, this argument is the macro defined in a C language definition (the text immediately following `#define`), or the name of a variable in a makefile.
5. `value`—A default value assigned to the setting if the BSP user does not manually change it
6. `description`—Descriptive text, shown in the BSP **summary.html** document.

### Data Types

Several setting data types are available, controlled by the `type` argument to `add_sw_setting`. They correspond to the data types you can express as `#define` statements or values concatenated to makefile variables. The specific setting type depends on your software's structure or BSP build needs. The available data types, and their typical uses, are shown in [Table 7-5](#).

**Table 7-5.** Data Type Settings

Data Type	Setting Value	Notes
Boolean definition	<code>boolean_define_only</code>	A definition that is generated when true, and absent when false. Use a boolean definition in your C source files with the <code>#ifdef &lt;setting&gt; ... #endif</code> construct.
Boolean assignment	<code>boolean</code>	A definition assigned to 1 when true, 0 when false. Use a boolean assignment in your C source files with the <code>#if &lt;setting&gt; ... #else ...</code> construct.

**Table 7-5.** Data Type Settings

Data Type	Setting Value	Notes
Character	character	A definition with one character surrounded by single quotation marks (')
Decimal number	decimal_number	A definition with an unquoted, unformatted decimal number, such as 123. Useful for defining values in software that, for example, might have a configurable buffer size, such as <code>int buffer[SIZE];</code>
Double precision number	double	A definition with a double-precision floating point number such as 123.4
Floating point number	float	A definition with a single-precision floating point number such as 234.5
Hexadecimal number	hex_number	A definition with a number prefixed with 0x, such as 0x1000. Useful for specifying memory addresses or bit masks
Quoted string	quoted_string	A definition with a string in quotes, such as "Buffer"
Unquoted string	unquoted_string	A definition with a string not in quotes, such as BUFFER

### Setting Destination Files

The `destination` argument of `add_sw_setting` specifies settings and their assigned values. This argument controls the file to which the setting is saved in the BSP. The BSP generator formats the setting's assigned value based on the definition file and type of setting. Table 7-6 shows possible values of the `destination` argument.

**Table 7-6.** Destination File Settings

Destination File	Setting Value	Notes
<b>system.h</b>	system_h_define	This destination file is recommended in most cases. Your source code must use a <code>#include &lt;system.h&gt;</code> statement to make the setting definitions available. Settings appear as <code>#define</code> statements in <b>system.h</b> .
<b>public.mk</b>	public_mk_define	Definitions appear as <code>-D</code> statements in <b>public.mk</b> , in the C preprocessor flags assembly. This setting type is passed directly to the compiler during BSP and is visible during compilation of application and libraries referencing the BSP.
<b>BSP makefile</b>	makefile_variable	Settings appear as makefile variable assignments in the BSP makefile.



Certain setting types are not compatible with the **public.mk** or **Makefile** destination file types.



For detailed information, refer to the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*.



### Setting Display Name

The setting `displayName` controls what the end user of the driver or package (the BSP developer) types to control the setting in their BSP. BSPs append the `displayName` text after a `.` (dot) separator to your driver or software package's name (as defined in the `create_driver` or `create_sw_package` command). For example, if your driver is named `my_peripheral_driver` and your setting's `displayName` is `small_driver`, BSPs with your driver have a setting `my_peripheral_driver.small_driver`. Thus each driver and software package has its own settings namespace.

### Setting Generation Name

The setting `generationName` of `add_sw_setting` controls the physical name of the setting in the generated BSP files. The physical name corresponds to the definition being created in **public.mk** and **system.h**, or the make variable created in the BSP **Makefile**. The `generationName` is commonly the text that your software uses in conditionally-compiled code. For example, suppose your software creates a buffer as follows:

```
unsigned int driver_buffer[MY_DRIVER_BUFFER_SIZE];
```

You can enter the exact text, `MY_DRIVER_BUFFER_SIZE`, in the `generationName` argument.

### Setting Default Value

The `value` argument of `add_sw_setting` holds the default value of your setting. This value propagates to the generated BSP unless the end user of the driver or package (the BSP developer) changes the setting's assignment before BSP generation.



The value assigned to any setting, whether it is the default value in the driver or software package Tcl script, or entered by the user configuring the BSP, must be compatible with the selected setting.



For details, refer to the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*.

### Setting Description

The `description` argument of `add_sw_setting` contains a brief description of the setting. The `description` argument is required. Place quotation marks ( " ") around the text of the description. The description text appears in the generated BSP **summary.html** document.

### Setting Creation Example

**Example 7-5** implements a setting for a driver that has two variants of a function, one implementing a small driver (minimal code footprint) and the other a fast driver (efficient execution).



### Example 7-5. Supporting Driver Settings

```
#include "system.h"
#ifdef MY_CUSTOM_DRIVER_SMALL
int send_data( <args> )
{
    // Small implementation
}
#else
int send_data( <args> )
{
    // fast implementation
}
#endif
```

In [Example 7-5](#), a simple Boolean definition setting is added to your driver Tcl file. This feature allows BSP users to control your driver through the BSP settings interface. When users set the setting to true or 1, the BSP defines `MY_CUSTOM_DRIVER_SMALL` in either **system.h** or the BSP **public.mk** file. When the user compiles the BSP, your driver is compiled with the appropriate routine incorporated in the object file. When a user disables the setting, `MY_CUSTOM_DRIVER_SMALL` is not defined.

You add the `MY_CUSTOM_DRIVER_SMALL` setting to your driver as follows using the `add_sw_setting` Tcl command:

```
add_sw_setting boolean_define_only system_h_define small_driver
    MY_CUSTOM_DRIVER_SMALL false
    "Enable the small implementation of the driver for my_peripheral"
```



Each Tcl command must reside on a single line of the Tcl file. This example is wrapped due to space constraints.



Each argument has several variants. For detailed usage and restrictions, refer to the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*.

## Reducing Code Footprint

The HAL provides several options for reducing the size, or footprint, of the BSP code. Some of these options require explicit support from device drivers. If you need to minimize the size of your software, consider using one or both of the following techniques in your custom device driver:

- Provide reduced footprint drivers. This technique usually reduces driver functionality.
- Support the lightweight device driver API. This technique reduces driver overhead. It need not reduce functionality, but it might restrict your flexibility in using the driver.

These techniques are discussed in the following sections.

## Provide Reduced Footprint Drivers

The HAL defines a C preprocessor macro named `ALT_USE_SMALL_DRIVERS` that you can use in driver source code to provide alternate behavior for systems that require a minimal code footprint. If `ALT_USE_SMALL_DRIVERS` is not defined, driver source code implements a fully featured version of the driver. If the macro is defined, the source code might provide a driver with restricted functionality. For example a driver might implement interrupt-driven operation by default, but polled (and presumably smaller) operation if `ALT_USE_SMALL_DRIVERS` is defined.

When writing a device driver, if you choose to ignore the value of `ALT_USE_SMALL_DRIVERS`, the same version of the driver is used regardless of the definition of this macro.

You can enable `ALT_USE_SMALL_DRIVERS` in a BSP with the `hal.enable_reduced_device_drivers` BSP setting.



For further information, refer to the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*.

## Support the Lightweight Device Driver API

The lightweight device driver API allows you to minimize the overhead of character-mode device drivers. It does this by removing the need for the `alt_fd` file descriptor table, and the `alt_dev` data structure required by each driver instance.

If you want to support the lightweight device driver API on a character-mode device, you need to write at least one of the lightweight character-mode functions listed in [Table 7-7](#). Implement the functions needed by your software. For example, if you only use the device for `stdout`, you only need to implement the `<component class>_write()` function.

To support the lightweight device driver API, name your driver functions based on the component class name, as shown in [Table 7-7](#).

**Table 7-7.** Driver Functions for Lightweight Device Driver API

Function	Purpose	Example (1)
<code>&lt;component class&gt;_read()</code>	Implements character-mode read functions	<code>altera_avalon_jtag_uart_read()</code>
<code>&lt;component class&gt;_write()</code>	Implements character-mode write functions	<code>altera_avalon_jtag_uart_write()</code>
<code>&lt;component class&gt;_ioctl()</code>	Implements device-dependent functions	<code>altera_avalon_jtag_uart_ioctl()</code>

(1) Based on component `altera_avalon_jtag_uart`

When you build your BSP with `ALT_USE_DIRECT_DRIVERS` enabled, instead of using file descriptors, the HAL accesses your drivers with the following macros:

- `ALT_DRIVER_READ(instance, buffer, len, flags)`
- `ALT_DRIVER_WRITE(instance, buffer, len, flags)`
- `ALT_DRIVER_IOCTL(instance, req, arg)`

These macros are defined in `<Nios II EDS install path>/components/altera_hal/HAL/inc/sys/alt_driver.h`.

These macros, together with the system-specific macros that the Nios II Software Build Tools create in **system.h**, generate calls to your driver functions. For example, with lightweight drivers turned on, `printf()` calls the HAL `write()` function, which directly calls your driver's `<component class>_write()` function, bypassing file descriptors.

You can enable `ALT_USE_DIRECT_DRIVERS` in a BSP with the `hal.enable_lightweight_device_driver_api` BSP setting.



For further information, refer to the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*.

You can also take advantage of the lightweight device driver API by invoking `ALT_DRIVER_READ()`, `ALT_DRIVER_WRITE()` and `ALT_DRIVER_IOCTL()` in your application software. To use these macros, include the header file **sys/alt\_driver.h**. Replace the instance argument with the device instance name macro from **system.h**; or if you are confident that the device instance name will never change, you can use a literal string, for example `custom_uart_0`.

Another way to use your driver functions is to call them directly, without macros. If your driver includes functions other than `<component class>_read()`, `<component class>_write()` and `<component class>_ioctl()`, you must call those functions directly from your application.

## Namespace Allocation

To avoid conflicting names for symbols defined by devices in the SOPC Builder system, all global symbols need a defined prefix. Global symbols include global variable and function names. For device drivers, the prefix is the name of the SOPC Builder component followed by an underscore. Because this naming can result in long strings, an alternate short form is also permitted. This short form is based on the vendor name, for example `alt_` is the prefix for components published by Altera. It is expected that vendors test the interoperability of all components they supply.

For example, for the `altera_avalon_jtag_uart` component, the following function names are valid:

- `altera_avalon_jtag_uart_init()`
- `alt_jtag_uart_init()`

The following names are invalid:

- `avalon_jtag_uart_init()`
- `jtag_uart_init()`

As source files are located using search paths, these namespace restrictions also apply to file names for device driver source and header files.

## Overriding the Default Device Drivers

All SOPC Builder components can elect to provide a HAL device driver. Refer to “[Integrating a Device Driver in the HAL](#)” on page 7-17. However, if the driver supplied with a component is inappropriate for your application, you can override the default driver by supplying a different driver.

In the Nios II Software Build Tools for Eclipse, you can use the BSP Editor to specify a custom driver.



For information about selecting device drivers, refer to “Using the BSP Editor” in the [Getting Started with the Graphical User Interface](#) chapter of the *Nios II Software Developer's Handbook*

On the command line, you specify a custom driver with the following BSP Tcl command:

```
set_driver <driver name> <component name>
```

For example, if you are using the **nios2-bsp** command, you replace the default driver for `uart0` with a driver called `custom_driver` as follows:

```
nios2-bsp hal my_bsp --cmd set_driver custom_driver uart0
```

## Referenced Documents

This chapter references the following documents:

- [Overview](#) chapter of the *Nios II Software Developer's Handbook*
- [Getting Started with the Graphical User Interface](#) chapter of the *Nios II Software Developer's Handbook*
- [Getting Started from the Command Line](#) chapter of the *Nios II Software Developer's Handbook*
- [Nios II Software Build Tools](#) chapter of the *Nios II Software Developer's Handbook*
- [Overview of the Hardware Abstraction Layer](#) chapter of the *Nios II Software Developer's Handbook*
- [Developing Programs Using the Hardware Abstraction Layer](#) chapter of the *Nios II Software Developer's Handbook*
- [Exception Handling](#) chapter of the *Nios II Software Developer's Handbook*
- [Cache and Tightly-Coupled Memory](#) chapter of the *Nios II Software Developer's Handbook*
- [Ethernet and the NicheStack TCP/IP Stack - Nios II Edition](#) 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*
- [AN 459: Guidelines for Developing a Nios II HAL Device Driver](#)

- *NicheStack Technical Reference Manual*, available on the [Literature: Nios II Processor](#) page of the Altera website

## Document Revision History

Table 7–8 shows the revision history for this document.

**Table 7–8.** Document Revision History

Date & Document Version	Changes Made	Summary of Changes
November 2009 v9.1.0	Removed Nios II IDE-specific information	Introduced the Nios II Software Build Tools for Eclipse™
March 2009 v9.0.0	<ul style="list-style-type: none"> <li>■ Reorganized and updated information and terminology to clarify role of Nios II Software Build Tools.</li> <li>■ Incorporated information about Tcl-based device drivers and software packages, formerly in <i>Using the Nios II Software Build Tools</i>.</li> <li>■ Described use of the <code>INSTANCE</code> macro in software packages.</li> <li>■ Corrected minor typographical errors.</li> </ul>	Tcl-based device drivers and software packages
May 2008 v8.0.0	No change from previous release.	
October 2007 v7.2.0	Added documentation for HAL device driver development with the Nios II Software Build Tools.	—
May 2007 v7.1.0	<ul style="list-style-type: none"> <li>■ Added table of contents to “Introduction” section.</li> <li>■ Added Referenced Documents section.</li> </ul>	—
March 2007 v7.0.0	No change from previous release.	
November 2006 v6.1.0	<ul style="list-style-type: none"> <li>■ Add section “<a href="#">Reducing Code Footprint</a>”</li> <li>■ Replace lwIP driver section with NicheStack TCP/IP Stack driver section</li> </ul>	Lightweight device driver API and minimal file I/O API; NicheStack TCP/IP Stack support.
May 2006 v6.0.0	No change from previous release.	
October 2005 v5.1.0	Added <code>IOADDR_*</code> macro details to section “ <a href="#">Accessing Hardware</a> ”.	
May 2005 v5.0.0	Updated reference to version of lwIP from 0.7.2 to 1.1.0.	
December 2004 v1.1	Updated reference to version of lwIP from 0.6.3 to 0.7.2.	
May 2004 v1.0	Initial Release.	



This section provides information about several advanced programming topics. It includes the following chapters:

- Chapter 8, Exception Handling
- Chapter 9, Cache and Tightly-Coupled Memory
- Chapter 10, MicroC/OS-II Real-Time Operating System
- Chapter 11, Ethernet and the NicheStack TCP/IP Stack - Nios II Edition
- Chapter 12, Read-Only Zip File System
- Chapter 13, Publishing Component Information to Embedded Software





## Introduction

This chapter discusses how to write programs to handle exceptions in the Nios® II processor architecture. Emphasis is placed on how to process hardware interrupt requests by registering a user-defined interrupt service routine (ISR) with the hardware abstraction layer (HAL). This information applies to software projects created with the Nios II Software Build Tools, either in Eclipse™ or on the command line.

This chapter contains the following sections:

- “Introduction” on page 8–1
- “Nios II Exception Handling Overview” on page 8–1
- “Interrupt Service Routines” on page 8–7
- “Improving ISR Performance” on page 8–18
- “Debugging ISRs” on page 8–25
- “HAL Exception Handling System Implementation” on page 8–26
- “The Instruction-Related Exception Handler” on page 8–32
- “Referenced Documents” on page 8–35



For low-level details about handling exceptions and hardware interrupts on the Nios II architecture, refer to the *Programming Model* chapter of the *Nios II Processor Reference Handbook*.

## Nios II Exception Handling Overview

The Nios II processor provides the following exception types:

- Hardware interrupts
- Software exceptions, which fall into the following categories:
  - Unimplemented instructions
  - Software traps
  - Miscellaneous exceptions

The Nios II processor offers two distinct approaches to handling hardware interrupts:

- The internal interrupt controller (IIC)
- The external interrupt controller (EIC) interface

The interrupt controllers are discussed in detail in “[Interrupt Controllers](#)” on [page 8–3](#).

## Exception Handling Terminology


The following list of HAL terms outlines basic exception handling concepts:

- **Application context**—The status of the Nios II processor and the HAL during normal program execution, outside of exception funnels and handlers.
- **Context switch**—The process of saving the Nios II processor's registers on a software exception or hardware interrupt, and restoring them on return from the exception handling routine or ISR.
- **Exception**—A transfer of control away from a program's normal flow of execution, caused by an event, either internal or external to the processor, which requires immediate attention. Exceptions include software exceptions and hardware interrupts.
- **Exception context**—The status of the Nios II processor and the HAL after a software exception or hardware interrupt, when funnel code, a software exception handler, or an ISR is executing.
- **Exception handling system**—The complete system of software routines that service all exceptions, including hardware interrupts, and pass control to software exception handlers and ISRs as necessary.
- **Exception (or interrupt) latency**—The time elapsed between the event that causes the exception (such as an unimplemented instruction or interrupt request) and the execution of the first instruction at the exception (or interrupt vector) address.
- **Exception (or interrupt) response time**—The time elapsed between the event that causes the exception and the execution of the handler.
- **Exception overhead**—Additional processing required to service a software exception or hardware interrupt, including HAL-specific processing and RTOS-specific processing if applicable.
- **Funnel code**—HAL-provided code that sets up the correct processor environment for an exception-specific handler, such as an ISR.
- **Handler**—Code specific to the exception type. The handler code is distinct from the funnel code, which takes care of general exception overhead tasks.
- **Hardware interrupt**—An exception caused by an explicit hardware request signal from an external device. A hardware interrupt diverts the processor's execution flow to a interrupt service routine, to ensure that a hardware condition is handled in a timely manner.
- **Implementation-dependent instruction**—A Nios II processor instruction that is not supported on all implementations of the Nios II core. For example, the `mul` and `div` instructions are implementation-dependent, because they are not supported on the Nios II/e core.
- **Interrupt**—Hardware interrupt.
- **Interrupt controller**—Hardware enabling the Nios II processor to respond to an interrupt by transferring control to an interrupt service routine.
- **Interrupt request (IRQ)**—Hardware interrupt.
- **Interrupt service routine (ISR)**—A software routine that handles an individual hardware interrupt.

- Invalid instruction—An instruction that is not defined for any implementation of the Nios II processor.
- Maskable exceptions—Exceptions that can be disabled with the `status.PIE` flag, including internal hardware interrupts, maskable external hardware interrupts, and software exceptions, but not including nonmaskable external interrupts.
- Maximum disabled time—The maximum amount of continuous time that the system spends with maskable exceptions disabled.
- Maximum masked time—The maximum amount of continuous time that the system spends with a single interrupt masked.
- Miscellaneous exception—A software exception which is neither an unimplemented instruction nor a `trap` instruction. For further information, refer to “Miscellaneous Exceptions” on page 8-32.
- Nested interrupts—See pre-emption.
- Pre-emption—The process of a high-priority interrupt taking control when a lower-priority ISR is already running. Also: nested interrupts.
- Software exception—An exception caused by a software condition; that is, any exception other than a hardware interrupt. This includes unimplemented instructions and `trap` instructions.
- Unimplemented instruction—An implementation-dependent instruction that is not supported on the particular Nios II core implementation that is in your system. For example, in the Nios II/e core, `mul` and `div` are unimplemented.
- Worst-case exception (or interrupt) latency—The value of the exception (or interrupt) latency, including the maximum disabled time or maximum masked time. Including the maximum disabled or masked time accounts for the case when the exception (or interrupt) occurs at the beginning of the masked or disabled time.

## Interrupt Controllers

The configuration of Nios II exception processing depends on the type of hardware interrupt controller. You select the hardware interrupt controller when you instantiate the Nios II processor in SOPC Builder. This section describes the kinds of interrupt controllers available with the Nios II processor.

 For details about selecting a hardware interrupt controller, refer to the *Instantiating the Nios II Processor in SOPC Builder* chapter of the *Nios II Processor Reference Handbook*. For details about the VIC, refer to the *Vectored Interrupt Controller Core* chapter in *Volume 5: Embedded Peripherals* of the *Quartus® II Handbook*.

### Internal Interrupt Concepts

With the IIC, Nios II exception handling is implemented in classic RISC fashion. All exception types, including hardware interrupts, are dispatched through a single top-level exception funnel. This means that all exceptions (hardware and software) are handled by code residing at a single location, the exception address.

The IIC is a simple, nonvectored hardware interrupt controller. Upon receipt of an interrupt request, the IIC transfers control to the general exception address. The hardware indicates which IRQ is currently asserted, and allows software to mask individual interrupts.

With the IIC, the HAL interrupt funnel identifies the hardware interrupt cause in software, and dispatches the registered ISR.

The IIC is available in all revisions of the Nios II processor.

### External Interrupt Concepts

The EIC interface enables the Nios II processor to work with a separate external interrupt controller component. An EIC can be a custom component that you provide. Altera provides an example of an EIC, the vectored interrupt controller (VIC).

With an EIC, hardware interrupts are handled separately from software exceptions. Hardware interrupts have separate vectors and funnels. Each interrupt can have its own handler, or handlers can be shared. Software exception handling is the same as with the IIC.

The EIC interface provides extensive capabilities for customizing your interrupt hardware. You can design, connect and configure an interrupt controller that is optimal for your application.

When an external hardware interrupt occurs, the Nios II processor transfers control to an individual vector address, which can be unique for each interrupt. The HAL provides the following services:

- Registering ISRs
- Setting up the vector table
- Transferring control from the vector table to your ISR

An EIC can be used with shadow register sets. A shadow register set is a complete alternate set of Nios II general-purpose registers, which can be used to maintain a separate runtime context for an ISR.

An EIC provides the following information about each hardware interrupt:

#### Requested Handler Address

The requested handler address (RHA) specifies the address of the funnel associated with the hardware interrupt. The availability of an RHA for each interrupt allows the Nios II processor to jump directly to the interrupt funnel specific to the interrupting device, reducing interrupt latency.

#### Requested Interrupt Level

The Nios II processor uses the requested interrupt level (RIL) to prioritize the hardware interrupt request versus any interrupt it is currently processing. While handling an interrupt, the Nios II processor normally only takes higher-level interrupts.

### Requested Register Set

If shadow register sets are implemented on the Nios II core, an EIC specifies a requested register set (RRS) when it asserts an interrupt request. When the Nios II processor takes the hardware interrupt, the processor switches to the requested register set. When an interrupt has a dedicated register set, the ISR avoids the overhead of saving registers for a context switch.

Multiple hardware interrupts can be configured to share a register set. However, at run time, the Nios II processor does not allow pre-emption between interrupts assigned to the same register set unless this feature is specifically enabled. In this case, the ISRs must be written so as to avoid register corruption.



Refer to the *Vectored Interrupt Controller Core* chapter in *Volume 5: Embedded Peripherals of the Quartus II Handbook* for an example of a driver that manages pre-emption within a register set.

### Requested NMI Mode

If the interrupt is configured as a nonmaskable interrupt (NMI), the EIC asserts requested NMI (RNMI). Any hardware interrupt can be nonmaskable, depending on the configuration of the EIC. An NMI typically signals a critical system event requiring immediate handling, to ensure either system stability or deterministic real-time performance.

### Shadow Register Sets

Although shadow register sets can be implemented independently of the EIC interface, typically the two features are used together. Combining shadow register sets with an appropriate EIC, you can minimize or eliminate the context switch overhead for critical hardware interrupts.

## Latency and Response Time

Exception (interrupt) latency, as defined in the previous section, is the time required for the hardware to respond to an exception. Response time, in contrast, is the time required to begin executing code specific to the exception cause, such as a particular ISR. Response time includes latency plus the time required for the HAL to carry out some or all of the following overhead tasks:

- Context save—Saving registers on the stack
- RTOS context switch—Calling context-switch function(s) if an RTOS is implemented
- Dispatch handler—Determining the cause of the exception, and transferring control to a specific handler or ISR

If you are concerned with system performance, response time is the more important than latency, because it reflects the time elapsed between the physical event and the system's specific response to that event.

This section discusses the available options for exception handling, and their impact on latency and response time.

### Internal or External Interrupt Controller

The Nios II IIC is nonvectored, requiring the processor to dispatch ISRs with a software routine. An EIC, by contrast, can be vectored. With a vectored EIC, such as the Altera® VIC, ISR dispatch is managed by hardware, eliminating the processing time required for ISR dispatch, and substantially reducing hardware interrupt response time.

An EIC has no impact on software exception latency or response time.

### Shadow Register Sets

In conjunction with an EIC, shadow register sets speed up hardware interrupt response by making it unnecessary to save registers on the stack. This feature has no impact on interrupt latency, but significantly reduces interrupt response time.

Shadow register sets have no impact on software exception response time.

## How the Hardware Works

The Nios II processor can respond to exceptions including software exceptions and hardware interrupts. When the Nios II processor responds to an exception, it performs the following tasks:

1. Saves the status register in `estatus`. This means that if hardware interrupts are enabled, the `PIE` bit of `estatus` is set.
2. Disables hardware interrupts.
3. Saves the next execution address in `ea` (r29).
4. Transfers control to the appropriate exception address, as follows:
  - Software exception or internal hardware interrupt—Nios II processor general exception address
  - External hardware interrupt—Device-specific interrupt address

All Nios II exception types are precise. This means that after an exception is handled, the Nios II processor can re-execute the instruction that caused the exception.

The Nios II processor always re-executes the instruction after the software exception handler or ISR has completed, when the exception processing system returns to the application context.

Several exception types, such as the advanced exceptions, are optional in the Nios II processor core. The presence of these exception types depends on how the hardware designer configures the Nios II core at the time of hardware generation.

The processor's response to hardware interrupts depends on which interrupt controller is implemented. The following sections describe the hardware behavior with each interrupt controller.



For details about the Nios II processor exception controller and hardware interrupt controllers, including a list of optional exception types, refer to the *Processor Architecture* chapter of the *Nios II Processor Reference Handbook*.

### How the Internal Interrupt Controller Works

With the IIC, 32 independent hardware interrupt signals are available. These interrupt signals allow software to prioritize interrupts, although the interrupt signals themselves have no inherent priority.



With the IIC, Nios II exceptions are not vectored. Therefore, the same exception address receives control for all types of exceptions. The general exception funnel at that address must determine the type of software exception or hardware interrupt.

### How an External Interrupt Controller Works

With an EIC, the Nios II processor supports an arbitrary number of independent hardware interrupt signals. Interrupts are typically vectored, with interrupt priority levels associated in hardware. Vectoring allows the Nios II processor to transfer control directly to each ISR. Hardware interrupt levels allow the most critical interrupts to pre-empt lower-priority interrupts. Because both of these features are implemented in hardware, the system can handle an interrupt without executing general exception funnel code.



The details of hardware interrupt vectoring and prioritization are specific to the EIC implementation. To see an example of an EIC implementation, refer to the *Vectored Interrupt Controller Core* chapter in *Volume 5: Embedded Peripherals of the Quartus II Handbook*.



The HAL supports external interrupt controllers only if they are connected in one of the following ways:

- Directly to the Nios II EIC interface
- Through the daisy-chain port on another EIC

## Interrupt Service Routines

Software often communicates with peripheral devices using hardware interrupts. When a peripheral asserts its IRQ, it diverts the processor's normal execution flow. When such an interrupt occurs, an appropriate ISR must handle this interrupt and return the processor to its pre-interrupt state on completion.

When you create a board support package (BSP) project, the build tools include all needed device drivers. You do not need to write HAL ISRs unless you are interfacing to a custom peripheral. For reference purposes, this section describes the framework provided by HAL BSPs for handling hardware interrupts.

Refer to existing handlers for Altera SOPC Builder components for examples of how to write HAL ISRs.



For more details about the Altera-provided HAL handlers, refer to the *Developing Programs Using the Hardware Abstraction Layer* chapter of the *Nios II Software Developer's Handbook*.

## HAL APIs for Hardware Interrupts

The HAL provides an enhanced application program interface (API) for writing, registering and managing ISRs. This API is compatible with both internal and external hardware interrupt controllers.

Altera also supports a legacy hardware interrupt API. This API supports only the IIC. If you have a custom driver written prior to Nios II v9.1, it uses the legacy API.

Both interrupt APIs include the following types of routines:

- Routines to be called by a device driver to register an ISR
- Routines to be called by an ISR to manage its environment
- Routines to be called by BSP or application code to control ISR behavior

Both interrupt APIs support the following types of BSPs:

- HAL BSP without an RTOS
- HAL-based RTOS BSP, such as a MicroC/OS-II BSP



The legacy API is deprecated. Write new drivers using the enhanced API, even if they are only intended to support the IIC. Drivers for devices supporting an EIC must use the enhanced API. Existing legacy drivers continue to be supported until further notice. Make plans to port them to the enhanced API.

When an EIC is present, the controller's driver provides driver settings for the BSP, which can be used to configure the driver. The number and types of the settings depends on the EIC implementation and the number of EICs present.



For an example of EIC driver settings, refer to the *Vectored Interrupt Controller Core* chapter in *Volume 5: Embedded Peripherals* of the *Quartus II Handbook*.

### Selecting an Interrupt API

When the Software Build Tools create a BSP, they determine whether the BSP must implement the legacy interrupt API. Each driver that supports the enhanced API publishes this capability to the Software Build Tools through its `<driver name>_sw.tcl` file. The BSP implements the enhanced API if all drivers support it. It implements the legacy API only if required by the drivers.

In determining the interrupt API to use, the Software Build Tools ignore any devices whose interrupts are not connected to the Nios II processor associated with the BSP.


A driver can publish its interrupt API support by way of a software property. The driver's `<driver name>_sw.tcl` file uses the `set_sw_property` command to set `supported_interrupt_apis` to either `legacy_interrupt_api`, `enhanced_interrupt_api`, or `both`.

Drivers supporting the enhanced API always publish that support. If `supported_interrupt_apis` is undefined, the Software Build Tools assume that the driver only supports the legacy API.

Starting in 9.1, all Altera device drivers support both APIs. These drivers can be used in a BSP along with legacy drivers. The Software Build Tools determine whether the legacy API is required, and implement it only if it is required. If there are no drivers requiring the legacy API, the BSP implements the enhanced API.



A driver can be written to support only the enhanced API. However, you cannot combine such a driver with legacy drivers.

 For details about writing a driver to support both APIs, refer to “Supporting Multiple Interrupt APIs” on page 8-11.


### The Enhanced HAL Interrupt API

The enhanced HAL interrupt API defines the functions listed in Table 8-1 to manage hardware interrupt processing.

**Table 8-1.** Enhanced HAL Interrupt API Functions

Function Name	Implemented By
<code>alt_ic_isr_register()</code>	Interrupt controller driver (1)
<code>alt_ic_irq_enable()</code>	Interrupt controller driver (1)
<code>alt_ic_irq_disable()</code>	Interrupt controller driver (1)
<code>alt_ic_irq_enabled()</code>	Interrupt controller driver (1)
<code>alt_irq_disable_all()</code>	HAL
<code>alt_irq_enable_all()</code>	HAL
<code>alt_irq_interruptible()</code>	HAL
<code>alt_irq_enabled()</code>	HAL
<b>Note to Table 8-1:</b> (1) If the system is based on an EIC, these functions must be implemented by the EIC driver. If the system is based in the IIC, the functions are implemented by the HAL. For details about each function, refer to the <i>HAL API Reference</i> chapter of the <i>Nios II Software Developer's Handbook</i> .	

The functions in Table 8-1 work for both internal and external interrupt controllers.

 For details about the enhanced interrupt API functions, refer to the *HAL API Reference* chapter of the *Nios II Software Developer's Handbook*.

Using the enhanced HAL API to implement ISRs requires that you perform the following steps:

1. Write your ISR that handles hardware interrupts for a specific device.
2. Ensure that your program registers the ISR with the HAL by calling the `alt_ic_isr_register()` function. `alt_ic_isr_register()` enables hardware interrupts for you.

The Software Build Tools insert the following symbol definitions in **system.h**, indicating the configuration of the processor's interrupt-related hardware options:

- **NIOS2\_EIC\_PRESENT**—If defined, indicates that one or more EICs are present
- **NIOS2\_NUM\_OF\_SHADOW\_REG\_SETS**—Indicates how many shadow register sets are present. The maximum value is 63. If there are no shadow register sets, the value is 0.

### The External Interrupt Controller Driver

To be compliant with the HAL enhanced interrupt API, the driver for an EIC must support the functions listed under “[The Enhanced HAL Interrupt API](#)”. In addition, it can provide functions to support any special hardware features. For examples, refer to “[Using the HAL Interrupt API with the VIC](#)”.

### Using the HAL Interrupt API with the VIC

The Altera driver for the VIC component supports the HAL enhanced interrupt API.

The VIC driver provides support for multiple, daisy-chained VIC devices. It also includes support for shadow register sets. A BSP driver setting allows you to enable automatic pre-emption (fast nested interrupts). Automatic pre-emption means that the Nios II processor leaves maskable exceptions enabled when accepting a hardware interrupt.



For more information about fast nested interrupts, refer to “Exception Processing” in the [Programming Model](#) chapter of the *Nios II Processor Reference Handbook*.

The VIC device driver also provides the following device-specific functions:

```
■ int alt_vic_sw_interrupt_set(alt_u32 ic_id, alt_u32 irq);
■ int alt_vic_sw_interrupt_clear(alt_u32 ic_id, alt_u32 irq);
■ alt_u32 alt_vic_sw_interrupt_status(alt_u32 ic_id, alt_u32
  irq);
■ int alt_vic_irq_set_level(alt_u32 ic_id, alt_u32 irq, alt_u32
  level);
```



For a detailed discussion of the VIC device-specific driver routines, refer to the [Vectored Interrupt Controller Core](#) chapter in *Volume 5: Embedded Peripherals* of the *Quartus II Handbook*.

The EIC driver controls where hardware interrupt vector tables are located. For example, the Altera VIC driver locates the vector table in the `.text` section by default, but allows you to position the vector table in a different section with a driver setting.



The memory in which you place the vector table must be connected to both instruction and data master ports on the Nios II processor.

### The Legacy HAL Interrupt API

The legacy HAL interrupt API defines the following functions to manage hardware interrupt processing:

```
■ alt_irq_register()
■ alt_irq_disable()
■ alt_irq_enable()
■ alt_irq_disable_all()
■ alt_irq_enable_all()
```

- `alt_irq_interruptible()`
- `alt_irq_non_interruptible()`
- `alt_irq_enabled()`



For details about these functions, refer to the *HAL API Reference* chapter of the *Nios II Software Developer's Handbook*.

Legacy drivers do not define the `supported_interrupt_apis` property. The absence of this property indicates to the Software Build Tools that they require the legacy interrupt API.

Using the legacy HAL API to implement ISRs requires that you perform the following steps:

1. Write your ISR that handles hardware interrupts for a specific device.
2. Ensure that your program registers the ISR with the HAL by calling the `alt_irq_register()` function. `alt_irq_register()` enables hardware interrupts for you, by calling `alt_irq_enable_all()`.

### Supporting Multiple Interrupt APIs

When you write or update a custom device driver, Altera recommends that you write it in one of two ways:

- Write it to support the enhanced HAL interrupt API—Write the driver this way if you intend to use it only in combination with other drivers supporting the enhanced API.
- Write it to support both the enhanced and the legacy API—Write the driver this way if you need to use it in combination with legacy drivers supporting only the legacy API.



Altera recommends using the enhanced API even if your Nios II processor implements the IIC. The enhanced API supports both types of interrupt controller, and the legacy API is deprecated.

When the Software Build Tools select the interrupt API, they define one of the following symbols in **system.h**, to identify which interrupt API is available:

- `ALT_ENHANCED_INTERRUPT_API_PRESENT`—Defined if the enhanced API is implemented
- `ALT_LEGACY_INTERRUPT_API_PRESENT`—Defined if the legacy API is implemented

In your driver code, use these symbols to determine which API calls to make.

To support both APIs, your driver must publish its interrupt API support by way of a software property. In your driver's `<driver name>_sw.tcl` file, use the `set_sw_property` command to set `supported_interrupt_apis` to both `legacy_interrupt_api` and `enhanced_interrupt_api`.



For details about the `set_sw_property` command, refer to the “Tcl Commands” section of the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*.

## HAL ISR Restrictions

When your system has an EIC, the HAL interrupt support imposes the following restrictions:

- Nonmaskable hardware interrupts must use a shadow register set.
- Nonmaskable hardware interrupts cannot share a register set with a maskable hardware interrupt.

## Writing an ISR

The ISR you write must match the prototype that `alt_ic_isr_register()` expects. The prototype for your ISR function must match the following prototype:

```
void (*alt_isr_func) (void* isr_context)
```

The parameter definition of `context` is the same as for the `alt_ic_isr_register()` function.

From the point of view of the HAL exception handling system, the most important function of an ISR is to clear the associated peripheral's interrupt condition. The procedure for clearing an hardware interrupt condition is specific to the peripheral.



For details, refer to the relevant chapter in *Volume 5: Embedded Peripherals* of the *Quartus II Handbook*.

When the ISR has finished servicing the hardware interrupt, it must return to the HAL interrupt funnel that called it.



If you write your ISR in assembly language, use `ret` to return. The HAL interrupt funnel issues an `eret` after restoring the application context.

## Using Interrupt Funnels

The HAL creates a vector table for each EIC connected to the Nios II processor. In the vector table, the HAL inserts a branch to the correct funnel for each interrupt-driven device supported by the BSP, depending on the device driver characteristics and pre-emption settings. Funnels can be shared by multiple hardware interrupts, if the drivers have compatible characteristics.

The funnel code receives control from the general exception or interrupt vector, depending on which interrupt controller is implemented. The funnel performs tasks such as switching the stack pointer, saving registers and calling RTOS context-switch routines, and transfers control to the handler. When the handler returns, the funnel code performs tasks such as calling RTOS process-dispatch routines and restoring registers, and transfers control to the appropriate foreground task.

The HAL includes the following interrupt funnels:

- Shadow register set, pre-emption disabled—Hardware interrupt assigned to a shadow register set, with pre-emption within the register set disabled. This funnel does not preserve register context. Hardware guarantees that only one ISR runs with the shadow register set at any time.
- Shadow register set, pre-emption enabled—Hardware interrupt assigned to a shadow register set. An interrupt can pre-empt another interrupt using the same register set. This funnel preserves register context, so that handlers assigned to the same register set do not corrupt one another's context.
- Nonmaskable interrupt—Nonmaskable hardware interrupt assigned to a shadow register set, with pre-emption within the register set disabled. This funnel does not preserve register context. Hardware guarantees that only one ISR runs in the shadow register set at any time.

The HAL funnel code is called from the vector table.

### Running in a Restricted Environment

ISRs run in a restricted environment. A large number of the HAL API calls are not available from ISRs. For example, accesses to the HAL file system are not permitted. As a general rule, when writing your own ISR, never include function calls that can block for any reason (such as waiting for a hardware interrupt).



The *HAL API Reference* chapter of the *Nios II Software Developer's Handbook* identifies those API functions that are not available to ISRs.

Be careful when calling ANSI C standard library functions inside of an ISR. Avoid using the C standard library I/O API, because calling these functions can result in deadlock within the system, that is, the system can become permanently blocked in the ISR.

In particular, do not call `printf()` from within an ISR unless you are certain that `stdout` is mapped to a non-interrupt-based device driver. Otherwise, `printf()` can deadlock the system, waiting for a hardware interrupt that never occurs because interrupts are disabled.


### Managing Pre-Emption

The HAL enhanced interrupt API supports interrupt pre-emption. When pre-emption is enabled, a higher-level interrupt can take control even if an ISR is already running. A device driver must be specifically written to function correctly under pre-emption. When a device driver supports pre-emption, it publishes this capability through the `isr_preemption_supported` driver setting. When constructing the BSP, the Software Build Tools check each device driver to determine whether it supports pre-emption. If all drivers in the BSP support pre-emption, it is enabled.

Legacy device drivers do not publish the `isr_preemption_supported` property. Therefore the Software Build Tools assume that they do not support pre-emption. If your legacy custom driver supports pre-emption, and you want to allow pre-emption in the BSP, you must update the driver to use the enhanced interrupt API.



To enable the enhanced interrupt API, ensure that all drivers in the system are updated to use the enhanced interrupt API.

 For details about the `isr_preemption_supported` driver setting, refer to the `set_sw_property` command in the “Tcl Commands” section of the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*.

Operating systems can also publish the `isr_preemption_supported` property.

The HAL enhanced interrupt API supports automatic pre-emption. Automatic pre-emption means that maskable exceptions remain enabled when the processor accepts the hardware interrupt. This means that your ISR can immediately be pre-empted by a higher-level ISR, without any need to execute the `eret` instruction.

Automatic pre-emption can only take place when the pre-empting hardware interrupt uses a different register set from the interrupt being pre-empted.

Automatic pre-emption is only available if you enable it in the BSP settings.

## Registering an ISR with the Enhanced Interrupt API

Before the software can use an ISR, you must register it by calling `alt_ic_isr_register()`. The prototype for `alt_ic_isr_register()` is:


```
int alt_ic_isr_register(alt_u32 ic_id,
                      alt_u32 irq,
                      alt_isr_func isr,
                      void *isr_context,
                      void* flags)
```

The function has the following parameters:

- `ic_id` is the interrupt controller identifier (ID) as defined in **system.h**. With daisy-chained EICs, `ic_id` identifies the EIC in the daisy chain. With the IIC, `ic_id` is not significant.
- `irq` is the hardware interrupt number for the device, as defined in **system.h**.
  - For the IIC, `irq` is the IRQ number. Interrupt priority corresponds inversely to the IRQ number. Therefore, `IRQ0` represents the highest priority interrupt and `IRQ31` is the lowest.
  - For an EIC, `irq` is the interrupt port ID.
- `isr_context` points to a data structure associated with the device driver instance. `isr_context` is passed as the input argument to the `isr` function. It is used to pass context-specific information to the ISR, and can point to any ISR-specific information. The context value is opaque to the HAL; it is provided entirely for the benefit of the user-defined ISR.
- `isr` is a pointer to the ISR function that is called in response to IRQ number `irq`. The ISR function prototype is:

```
void (void* isr_context);
```

The input argument provided to this function is the `isr_context`.

 Registering a null pointer for `isr` results in the interrupt being disabled.

- `flags` is reserved.

The HAL registers the ISR by one of the following methods:

- For the IIC, by the storing the function pointer, `isr`, in a lookup table.

- For an EIC, by configuring the vector table with the appropriate funnel code, as described in [“Using Interrupt Funnels” on page 8-12](#).

The return code from `alt_ic_isr_register()` is zero if the function succeeded, and nonzero if it failed.

If the HAL registers your ISR successfully, the associated Nios II hardware interrupt (as defined by `irq`) is enabled on return from `alt_ic_isr_register()`.



Hardware-specific initialization might also be required.

When a specific interrupt occurs, the HAL code ensures that the registered ISR is correctly dispatched.



For details about hardware interrupt initialization specific to your peripheral, refer to the relevant chapter of *Volume 5: Embedded Peripherals* of the *Quartus II Handbook*. For details about `alt_ic_isr_register()`, refer to the *HAL API Reference* chapter of the *Nios II Software Developer's Handbook*.



The HAL legacy interrupt API provides a different function for registering hardware interrupts. For all new and updated drivers, Altera recommends using the enhanced API described in this section. The legacy API function, `alt_irq_register()`, is described in the *HAL API Reference* chapter of the *Nios II Software Developer's Handbook*.

## Enabling and Disabling Interrupts

The HAL enhanced interrupt API provides the functions `alt_ic_irq_disable()`, `alt_ic_irq_enable()`, `alt_ic_irq_enabled()`, `alt_irq_disable_all()`, `alt_irq_enable_all()`, and `alt_irq_enabled()` to allow a program to disable hardware interrupts for certain sections of code, and reenable them later.

`alt_ic_irq_disable()` and `alt_ic_irq_enable()` allow you to disable and enable individual interrupts. `alt_irq_disable_all()` disables all interrupts, and returns a context value. To reenable hardware interrupts, you call `alt_irq_enable_all()` and pass in the context parameter. In this way, interrupts are returned to their state prior to the call to `alt_irq_disable_all()`. `alt_irq_enabled()` returns nonzero if maskable exceptions are enabled. `alt_ic_irq_enabled()` determines whether a specified interrupt is enabled.



Disable hardware interrupts for as short a time as possible. Maximum interrupt latency increases with the longest amount of time interrupts are disabled. For more information about disabled interrupts, refer to [“Keep Interrupts Enabled” on page 8-19](#).



For details about these functions, refer to the *HAL API Reference* chapter of the *Nios II Software Developer's Handbook*.



The HAL legacy interrupt API provides different functions for enabling and disabling individual interrupts. For all new and updated drivers, Altera recommends using the enhanced API described in this section. The legacy API functions, `alt_irq_disable()` and `alt_irq_enable()`, are described in the *HAL API Reference* chapter of the *Nios II Software Developer's Handbook*.

## Configuring an External Interrupt Controller

The driver for an EIC provides specialized driver settings that are created at the time you generate the BSP. These settings customize the driver to the EIC configuration found in the Nios II system. The number and type of settings depends on the EIC implementation, as well as on the number and configuration of EICs in the hardware system. The Software Build Tools create the BSP with default values, selected to ensure useful system performance. You can optimize these settings at the time you create the BSP. For details of how to manipulate the EIC driver settings, refer to the documentation for your specific EIC.

The driver for an EIC can provide specialized functions to manage any implementation-specific features of the EIC. An example would be modifying interrupt priority levels at runtime.



For examples, refer to the *Vectored Interrupt Controller Core* chapter in *Volume 5: Embedded Peripherals* of the *Quartus II Handbook*.

## C Example

**Example 8-1** illustrates an ISR that services a hardware interrupt from a button parallel I/O (PIO) component. This example is based on a Nios II system with a 4-bit PIO peripheral connected to push buttons. An IRQ is generated any time a button is pushed. The ISR code reads the PIO peripheral's edge capture register and stores the value to a global variable. The address of the global variable is passed to the ISR in the context pointer.

### Example 8-1. An ISR to Service a Button PIO Interrupt

```
#include "system.h"
#include "altera_avalon_pio_regs.h"
#include "alt_types.h"

#ifdef ALT_ENHANCED_INTERRUPT_API_PRESENT
static void handle_button_interrupts(void* context)
#else
static void handle_button_interrupts(void* context, alt_u32 id)
#endif
{
    /* Cast context to edge_capture's type. It is important that this
       be declared volatile to avoid unwanted compiler optimization. */
    volatile int* edge_capture_ptr = (volatile int*) context;

    /*
     * Read the edge capture register on the button PIO.
     * Store value.
     */
    *edge_capture_ptr =
        IORD_ALTERA_AVALON_PIO_EDGE_CAP(BUTTON_PIO_BASE);

    /* Write to the edge capture register to reset it. */
    IOWR_ALTERA_AVALON_PIO_EDGE_CAP(BUTTON_PIO_BASE, 0);

    /* Read the PIO to delay ISR exit. This is done to prevent a
       spurious interrupt in systems with high processor -> pio
       latency and fast interrupts. */
    IORD_ALTERA_AVALON_PIO_EDGE_CAP(BUTTON_PIO_BASE);
}
```



**Example 8-2** shows an example of the code for the main program that registers the ISR with the HAL.

Based on this code, the following execution flow is possible:

1. Button is pressed, generating an IRQ.
2. The ISR gains control.
  - With the IIC, the HAL general exception funnel gains control of the processor, and dispatches the `handle_button_interrupts()` ISR.
  - With an EIC, the processor branches to the address in the vector table, which transfers control to the `handle_button_interrupts()` ISR.
3. `handle_button_interrupts()` services the hardware interrupt and returns.
4. Normal program operation continues with an updated value of `edge_capture`.

---

**Example 8-2.** Registering the Button PIO ISR with the HAL

---

```
#include "sys/alt_irq.h"
#include "system.h"

...
/* Declare a global variable to hold the edge capture value. */
volatile int edge_capture;
...

/* Initialize the button_pio. */
static void init_button_pio()
{
    /* Recast the edge_capture pointer to match the
       alt_irq_register() function prototype. */
    void* edge_capture_ptr = (void*) &edge_capture;

    /* Enable all 4 button interrupts. */
    IOWR_ALTERA_AVALON_PIO_IRQ_MASK(BUTTON_PIO_BASE, 0xf);

    /* Reset the edge capture register. */
    IOWR_ALTERA_AVALON_PIO_EDGE_CAP(BUTTON_PIO_BASE, 0x0);

    /* Register the ISR. */
#ifdef ALT_ENHANCED_INTERRUPT_API_PRESENT
    alt_ic_isr_register(BUTTON_PIO_IRQ_INTERRUPT_CONTROLLER_ID,
                       BUTTON_PIO_IRQ,
                       handle_button_interrupts,
                       edge_capture_ptr, 0x0);
#else
    alt_irq_register( BUTTON_PIO_IRQ,
                     edge_capture_ptr,
                     handle_button_interrupts );
#endif
}
```

---



Additional software examples that demonstrate implementing ISRs, such as the `count_binary` example project template, are installed with the Nios II Embedded Design Suite (EDS).

## Upgrading to the Enhanced HAL Interrupt API

If you have custom device drivers, Altera recommends that you upgrade them to use the enhanced HAL interrupt API. The enhanced API maintains compatibility with the IIC, while supporting external interrupt controllers. The legacy HAL interrupt API is deprecated, and will be removed in a future release of the Nios II EDS.

If you plan to use an EIC, you must upgrade your custom driver to the enhanced HAL interrupt API.

Upgrading your device driver is very simple, requiring only minor changes to some function calls.

Table 8-2 shows the legacy API functions that need to be modified, with the corresponding enhanced API functions.



For details of the API functions, refer to the *HAL API Reference* chapter of the *Nios II Software Developer's Handbook*.

**Table 8-2.** HAL Interrupt API Functions to Upgrade

Legacy API Function	Enhanced API Function
<code>alt_irq_register()</code>	<code>alt_ic_isr_register()</code>
<code>alt_irq_disable()</code>	<code>alt_ic_irq_disable()</code>
<code>alt_irq_enable()</code>	<code>alt_ic_irq_enable()</code>



If your upgraded driver might need to function in a BSP with legacy drivers, code it to support both APIs, as described in “Supporting Multiple Interrupt APIs” on page 8-11.

## Improving ISR Performance

If your software uses hardware interrupts extensively, the performance of ISRs is probably the most critical determinant of your overall software performance. This section discusses both hardware and software strategies to improve ISR performance.

### Software Performance Improvements

In improving your ISR performance, you probably consider software changes first. However, in some cases it might require less effort to implement hardware design changes that increase system efficiency. For a discussion of hardware optimizations, refer to “Hardware Performance Improvements” on page 8-23.

The following sections describe changes you can make in the software design to improve ISR performance.

#### Execute Time-Intensive Algorithms in the Application Context

ISRs provide rapid, low latency response to changes in the state of hardware. They do the minimum necessary work to clear the hardware interrupt condition and then return. If your ISR performs lengthy, noncritical processing, it can interfere with more critical tasks in the system.

If your ISR requires lengthy processing, design your software to perform this processing outside of the exception context. The ISR can use a message-passing mechanism to notify the application code to perform the lengthy processing tasks.

Deferring a task is simple in systems based on an RTOS such as MicroC/OS-II. In this case, you can create a thread to handle the processor-intensive operation, and the ISR can communicate with this thread using any of the RTOS communication mechanisms, such as event flags or message queues.

You can emulate this approach in a single-threaded HAL-based system. The main program polls a global variable managed by the ISR to determine whether it needs to perform the processor-intensive operation.

### Implement Time-Intensive Algorithms in Hardware

Processor-intensive tasks must often transfer large amounts of data to and from peripherals. A general-purpose processor such as the Nios II processor is not the most efficient way to do this. Use direct memory access (DMA) hardware if it is available.



For information about programming with DMA hardware, refer to “Using DMA Devices” in the *Developing Programs Using the Hardware Abstraction Layer* chapter of the *Nios II Software Developer’s Handbook*.

### Increase Buffer Size

If you are using DMA to transfer large data buffers, the buffer size can affect performance. Small buffers imply frequent interrupts, which lead to high overhead.

Increase the size of the transaction data buffer(s).

### Use Double Buffering

Using DMA to transfer large data buffers might not provide a large performance increase if the Nios II processor must wait for DMA transactions to complete before it can perform the next task.

Double buffering allows the Nios II processor to process one data buffer while the hardware is transferring data to or from another.

### Keep Interrupts Enabled

When interrupts are disabled, the Nios II processor cannot respond quickly to hardware interrupt events. Buffers and queues can fill or overflow. Even in the absence of overflow, maximum interrupt processing time can increase after interrupts are re-enabled, because the ISRs must process data backlogs.

Disable interrupts as infrequently as possible, and for the briefest time possible.

Instead of disabling all interrupts, call `alt_ic_irq_disable()` and `alt_ic_irq_enable()` to enable and disable individual interrupts.

To protect shared data structures, use RTOS structures such as semaphores.

Disable all interrupts only during critical system operations. In the code where interrupts are disabled, perform only the bare minimum of critical operations, and reenables interrupts immediately.

## Use Fast Memory

ISR performance depends on memory speed.

For best performance, place the ISRs and the stack in the fastest available memory: preferably tightly-coupled memory (if available), or on-chip memory.

If it is not possible to place the main stack in fast memory, consider using a separate exception stack, mapped to a fast memory section, as described in the next section.



For more information about mapping memory, refer to “Memory Usage” in the *Developing Programs Using the Hardware Abstraction Layer* chapter of the *Nios II Software Developer’s Handbook*. For more information about tightly-coupled memory, refer to the *Cache and Tightly-Coupled Memory* chapter of the *Nios II Software Developer’s Handbook*.

## Use a Separate Exception Stack

The HAL implements two types of separate exception stack. Their availability depends on the interrupt controller, as described in this section. Table 8–3 outlines the availability of separate exception stacks, and how they can be used with each type of interrupt controller.



Using a separate exception stack entails a slight additional overhead. When processing a software exception or hardware interrupt, the processor must execute an additional instruction on entry and exit, to change the stack pointer. Take this additional processing time into account if your interrupt response requirements are extremely strict.

### Separate General Exception Stack

The separate general exception stack is available with either the internal or the external interrupt controller.

Use the `hal.linker.enable_exception_stack` BSP setting to enable a separate general exception stack.

The HAL general exception funnel code takes care of correctly changing the stack pointer on entry to and exit from an exception handler.

### Separate Hardware Interrupt Stack

The separate hardware interrupt stack is available with the EIC interface. The separate hardware interrupt stack is not applicable to the IIC. With the IIC, hardware interrupts and software exceptions use the same stack.

The following BSP settings enable you to control the separate hardware interrupt stack:

- `hal.linker.enable_interrupt_stack` enables a separate hardware interrupt stack.
- `hal.linker.interrupt_stack_size` controls the size of the hardware interrupt stack.
- `hal.linker.interrupt_stack_memory_region_name` enables you to control where the hardware interrupt stack is positioned in memory.

The HAL funnel code takes care of correctly changing the stack pointer on entry to and exit from an ISR.

**Table 8-3.** Separate Exception Stack Usage

Interrupt Controller	BSP Settings		Application Stack	General Exception Stack	Hardware Interrupt Stack
	Separate General Exception Stack Enabled	Separate Hardware Interrupt Stack Enabled			
Internal	No	—	<ul style="list-style-type: none"> <li>■ Application</li> <li>■ Software exceptions</li> <li>■ Hardware interrupts</li> </ul>	—	—
	Yes	—	Application	<ul style="list-style-type: none"> <li>■ Software exceptions</li> <li>■ Hardware interrupts</li> </ul>	—
External	No	No	<ul style="list-style-type: none"> <li>■ Application</li> <li>■ Software exceptions</li> <li>■ Hardware interrupts</li> </ul>	—	—
		Yes	<ul style="list-style-type: none"> <li>■ Application</li> <li>■ Software exceptions</li> </ul>	—	Hardware interrupts
	Yes	No	<ul style="list-style-type: none"> <li>■ Application</li> <li>■ Hardware interrupts</li> </ul>	Software exceptions	—
		Yes	Application	Software exceptions	Hardware interrupts



If your ISR is located in a vector table, the HAL does not provide funnel code. In this case, your code must manage the stack pointer, as well as all other funnel code functions.



For further details about implementing a separate hardware interrupt stack, refer to *AN595: Vectored Interrupt Controller Applications and Usage*.

### Use Nested Hardware Interrupts

By default, the HAL disables interrupts when it dispatches an ISR. This means that only one ISR can execute at any time, and ISRs are executed on a first-come first-served basis. This reduces the system overhead associated with interrupt processing, and simplifies ISR development. The ISR does not need to be reentrant. ISRs can use and modify any global or static data structures or hardware registers that are not shared with application code.

However, first-come first-served execution means that the HAL hardware interrupt priorities only have an effect if two IRQs are active at the same time. A low-priority interrupt occurring before a higher-priority interrupt can prevent the higher-priority ISR from executing. This is a form of priority inversion, and it can have a significant impact on ISR performance in systems that generate frequent interrupts.

A software system can achieve full hardware interrupt prioritization by using nested ISRs. With nested ISRs, higher-priority interrupts are allowed to interrupt lower-priority ISRs.

This technique can improve the response time for higher-priority interrupts.



Nested ISRs increase the processing time for lower-priority hardware interrupts.

If your ISR is very short, it might not be worth the overhead to enable nested hardware interrupts. Enabling nested interrupts for a short ISR can actually increase the response time for higher-priority interrupts.



If you use a separate exception stack with the IIC, you cannot nest hardware interrupts. For more information about separate exception stacks, refer to [“Use a Separate Exception Stack”](#).

### Nested Hardware Interrupts with the Internal Interrupt Controller

To implement nested hardware interrupts with the IIC, use the `alt_irq_interruptible()` and `alt_irq_non_interruptible()` functions to bracket code in a processor-intensive ISR. The call to `alt_irq_interruptible()` adjusts the interrupt mask so that higher-priority interrupts can take control from the running ISR. When your ISR calls `alt_irq_non_interruptible()`, the interrupt mask is returned to its previous state.



If your ISR calls `alt_irq_interruptible()`, it must call `alt_irq_non_interruptible()` before returning. Otherwise, the HAL exception handling system might lock up.

### Nested Hardware Interrupts with an External Interrupt Controller

The HAL enhanced interrupt API supports nested hardware interrupts, also known as interrupt pre-emption. A device driver must be specifically written to function correctly under pre-emption.

Legacy device drivers do not publish the `isr_preemption_supported` property. Therefore the Software Build Tools assume that they do not support pre-emption. If your legacy custom driver supports pre-emption, and you want to allow pre-emption in the BSP, you must update the driver to use the enhanced HAL interrupt API.

The HAL enhanced interrupt API also supports automatic pre-emption. Automatic pre-emption means that maskable exceptions remain enabled when the processor accepts the hardware interrupt.



For details about pre-emption with an EIC, refer to [“Managing Pre-Emption” on page 8-13](#).

In the vector table, the HAL inserts a branch to the correct funnel for each hardware interrupt, depending on the pre-emption settings.

## Locate ISR Body in Vector Table

If you are using a vectored EIC, and you have a critical ISR of small size, you might achieve a performance improvement by positioning the ISR code directly in the vector table. In this way, you eliminate the overhead of branching from the vector table through the HAL funnel to your ISR.

The EIC's driver provides a default vector table entry size. For example, with the Altera VIC, the default size is 16 bytes. To accommodate your ISR, adjust the entry size with a driver setting when you create the BSP.



Positioning an ISR in a vector table is an advanced and error-prone technique, not directly supported by the HAL. You must exercise great caution to ensure that the ISR code fits in the vector table entry. If your ISR overflows the vector table entry, it corrupts other entries in the vector table, and your entire interrupt handling system. When your ISR is located in the vector table, it does not need to be registered. Do not call `alt_ic_isr_register()`, because it overwrites the contents of the vector table. The HAL does not provide funnel code. Therefore, your code must manage all funnel code functions.



For further details about locating an ISR in a vector table, refer to [AN595: Vectored Interrupt Controller Applications and Usage](#).

## Use Compiler Optimization

For the best performance both in exception context and application context, use compiler optimization level `-O3`. Level `-O2` also produces good results. Removing optimization altogether significantly increases exception response time.



For further information about compiler optimizations, refer to “Reducing Code Footprint” in the [Developing Programs Using the Hardware Abstraction Layer](#) chapter of the *Nios II Software Developer's Handbook*.

## Hardware Performance Improvements

Several simple hardware changes can provide a substantial improvement in ISR performance. These changes involve editing and regenerating the SOPC Builder module, and recompiling the Quartus® II design.

In some cases, these changes also require changes in the software architecture or implementation. For a discussion of these and other software optimizations, refer to [“Software Performance Improvements” on page 8–18](#).

The following sections describe changes you can make in the hardware design to improve ISR performance.

## Use Vectored Hardware Interrupts

By default, the Nios II processor has a nonvectored IIC. The HAL provides software to dispatch each hardware interrupt to its specific ISR. By contrast, vectoring allows the processor to transfer control directly to the ISR with minimal software intervention.

The options available for hardware interrupt vectoring depend on the interrupt controller configured in the Nios II hardware, as described in this section.

### Using the Interrupt Vector Custom Instruction

The Nios II processor core offers an interrupt vector custom instruction that accelerates hardware interrupt vector dispatch in the HAL. You can include this custom instruction to improve your program's interrupt response time.

When the interrupt vector custom instruction is present in the Nios II processor, the HAL source detects it at compile time and generates code using the custom instruction.



When using an interrupt vector custom instruction, you cannot use a separate exception stack.



For further information about the interrupt vector custom instruction, refer to "Interrupt Vector Custom Instruction" in the *Instantiating the Nios II Processor in SOPC Builder* chapter of the *Nios II Processor Reference Handbook*.

### Using an External Interrupt Controller

The Nios II EIC port allows you to connect a customizable external interrupt controller component. An EIC can be vectored. An example is the Altera VIC.



For details about the VIC, refer to the *Vectored Interrupt Controller Core* chapter in *Volume 5: Embedded Peripherals* of the *Quartus II Handbook*.

### Add Fast Memory

Increase the amount of fast on-chip memory available for data buffers. Ideally, implement tightly-coupled memory that the software can use for buffers.



For further information about tightly-coupled memory, refer to the *Cache and Tightly-Coupled Memory* chapter of the *Nios II Software Developer's Handbook*, or to the *Using Nios II Tightly Coupled Memory Tutorial*.

### Add a DMA Controller

A DMA controller performs bulk data transfers, reading data from a source address range and writing the data to a different address range. Add DMA controllers to move large data buffers. This allows the Nios II processor to carry out other tasks while data buffers are being transferred.



For information about DMA controllers, refer to the *DMA Controller Core* and *Scatter-Gather DMA Controller Core* chapters in *Volume 5: Embedded Peripherals* of the *Quartus II Handbook*.

### Place the Handler in Fast Memory

For the fastest execution of exception handler code, place the handler in a fast memory device. For example, an on-chip RAM with zero wait states is preferable to a slow SDRAM. For best performance, store exception handling code and data in tightly-coupled memory. The Nios II EDS includes example designs that demonstrate the use of tightly-coupled memory for ISRs.



### Use a Fast Nios II Core

For processing in both the exception context and the application context, the Nios II/f core is the fastest, and the Nios II/e core (designed for small size) is the slowest.

### Select Hardware Interrupt Priorities

Hardware interrupt priority levels can have a significant impact on system performance. If two interrupts can be asserted at the same time, it is important to assign a higher priority level to the more critical interrupt, so that it runs in preference to the less critical interrupt.

### Hardware Interrupt Priorities with the Internal Interrupt Controller

When selecting the IRQ for each peripheral, remember that the HAL hardware interrupt funnel treats IRQ<sub>0</sub> as the highest priority. Assign each peripheral's interrupt priority based on its need for fast servicing in the overall system. Avoid assigning multiple peripherals to the same IRQ.

### Hardware Interrupt Priorities with an External Interrupt Controller

With an EIC, the hardware interrupt priority level can be more flexible than with the IIC. The method of assigning priority levels to IRQs depends on the specific EIC implementation.

For example, with the Altera VIC, you can adjust hardware interrupt priority levels at runtime, with the `alt_vic_irq_set_level()` function.



For details about the VIC, refer to the *Vectored Interrupt Controller Core* chapter in *Volume 5: Embedded Peripherals* of the *Quartus II Handbook*.

## Debugging ISRs

You can debug an ISR by setting breakpoints in the ISR. The debugger completely halts the processor on reaching a breakpoint. In the meantime, however, the other hardware in your system continues to operate. Therefore, it is inevitable that other interrupts are ignored while the processor is halted. You can use the debugger to step through the ISR code, but the status of other interrupt-driven device drivers is generally invalid by the time you return the processor to normal execution. You must reset the processor to return the system to a valid state.

With the IIC, the `ipending` register (`ctl14`) is masked to all zeros during single-stepping. This masking prevents the processor from servicing interrupts that are asserted while you single-step through code. As a result, if you try to single-step through a part of the exception handling system that reads the `ipending` register, such as `alt_irq_entry()` or `alt_irq_handler()`, the code does not detect any pending interrupts. This issue does not affect debugging software exceptions. You can set breakpoints in your ISR code (and single-step through it), because the interrupt funnel has already used `ipending` to determine which device caused the hardware interrupt.

## HAL Exception Handling System Implementation

This section describes the HAL exception handling system implementation. This is one of many possible implementations of an exception handling system for the Nios II processor. Some features of the HAL exception handling system are constrained by the Nios II hardware, while others provide generally useful services.

You can take advantage of the HAL exception handling system without a complete understanding of the HAL implementation. For details about how to install ISRs using the HAL API, refer to [“Interrupt Service Routines” on page 8-7](#).

### Exception Handling System Structure

The exception handling system consists of the following components:

- The general exception funnel
- The software exception funnel
- The hardware interrupt funnel(s)
- An ISR for each peripheral that generates hardware interrupts

With the IIC, there is a single hardware interrupt funnel. This funnel manages processor context switch and RTOS overhead (if any). It determines the source of the IRQ, and dispatches the correct ISR.

With an EIC, hardware interrupt funnels are configured by the EIC driver. With a vectored EIC, such as the Altera VIC, there are multiple hardware interrupt funnels. Each funnel manages processor context switch if necessary, and RTOS overhead if any. ISR dispatch is managed by hardware.

With the IIC, when the Nios II processor generates an exception, the general exception funnel receives control. The general exception funnel passes control to either the hardware interrupt funnel or the software exception funnel. The hardware interrupt funnel passes control to one or more ISRs.

Each time an exception occurs, the exception handling system services either a software exception or hardware interrupts, with hardware interrupts having a higher priority. The HAL IIC support does not include nested exceptions, but can handle multiple hardware interrupts per context switch. For details, refer to [“Hardware Interrupt Funnel” on page 8-27](#).

With an EIC, the general exception funnel handles only software exceptions. An IRQ causes the processor to transfer control to one of the interrupt funnels, which branches directly to the ISR.

## General Exception Funnel

The general exception funnel provided with the HAL is located at the Nios II processor's exception address. When a software exception or internal hardware interrupt occurs, and control transfers to the general exception funnel, it does the following:

1. Switches to the separate exception stack (if enabled)
2. Stores register values onto the stack
3. Determines the type of exception, and passes control to the software exception funnel or the hardware interrupt funnel

### Hardware Interrupt Dispatch with the Internal Interrupt Controller

With the IIC, the general exception funnel dispatches hardware interrupts as well as software exceptions. [Figure 8-1](#) shows the algorithm that the HAL general exception funnel uses to distinguish between hardware interrupts and software exceptions.

The general exception funnel looks at the `estatus` register to determine the interrupt enable status. If the `PIE` bit is set, hardware interrupts were enabled at the time the exception happened. If so, the general exception funnel transfers control to the hardware interrupt funnel. The hardware interrupt funnel looks at the `IRQ` bits in `ipending`. If any `IRQs` are asserted, the interrupt funnel calls the appropriate hardware interrupt handler.

If hardware interrupts are not enabled at the time of the exception, it is not necessary to look at `ipending`.

If no `IRQs` are active, there is no hardware interrupt, and the exception is a software exception. In this case, the general exception funnel calls the software exception funnel.

All hardware interrupts are higher priority than software exceptions.



With an EIC, `IRQs` are dispatched by hardware. The HAL general exception funnel only handles software exceptions.



For details about the Nios II processor `estatus` and `ipending` registers, refer to the *Programming Model* chapter of the *Nios II Processor Reference Handbook*.

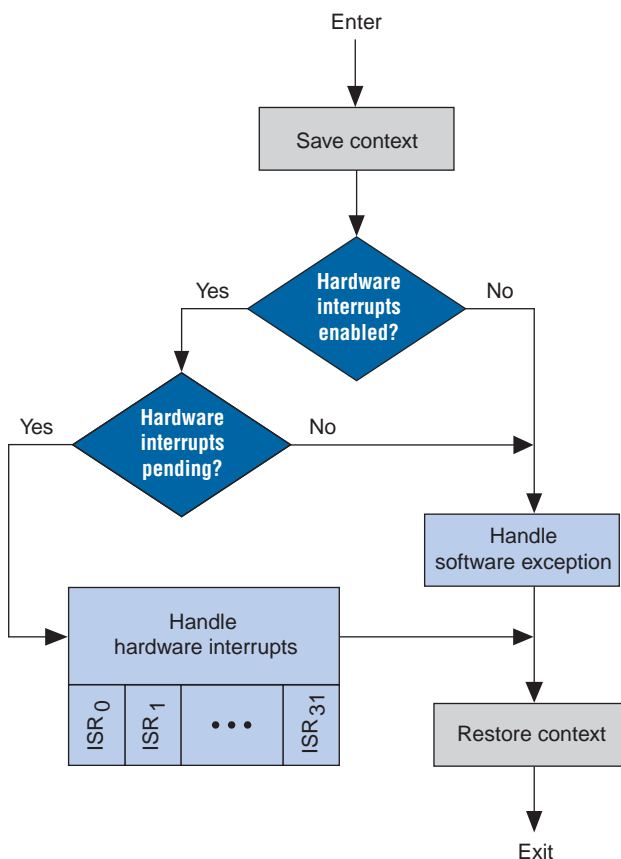
### Returning from Exceptions

After returning from the ISR or software exception handler, the general exception funnel performs the following tasks:

1. Restores the stack pointer, if a separate exception stack is used
2. Restores the registers from the stack
3. Exits by issuing an `eret` (exception return) instruction

## Hardware Interrupt Funnel

The configuration of the HAL hardware interrupt funnel depends on the interrupt controller implemented in the Nios II processor core.

**Figure 8-1.** HAL Exception Handling System with the Internal Interrupt Controller

### Interrupt Funnel for the Internal Interrupt Controller

With the IIC, the Nios II processor supports 32 hardware interrupts. In the HAL funnel, hardware interrupt 0 has the highest priority, and 31 the lowest. This prioritization is a feature of the HAL funnel, and is not inherent in the Nios II interrupt controller.

The hardware interrupt funnel calls the user-registered ISRs. It goes through the IRQs in `ipending` starting at 0, and finds the first (highest priority) active IRQ. Then it calls the corresponding registered ISR. After this ISR executes, the funnel begins scanning the IRQs again, starting at `IRQ0`. In this way, higher-priority interrupts are always processed before lower-priority interrupts. When all IRQs are clear, the hardware interrupt funnel returns to the top level. [Figure 8-2](#) shows a flow diagram of the HAL hardware interrupt funnel.

When the interrupt vector custom instruction is present in the Nios II processor, the HAL source detects it at compile time and generates code using the custom instruction. For further information, refer to [“Using the Interrupt Vector Custom Instruction” on page 8-24](#).

## Interrupt Funnels for External Interrupt Controllers

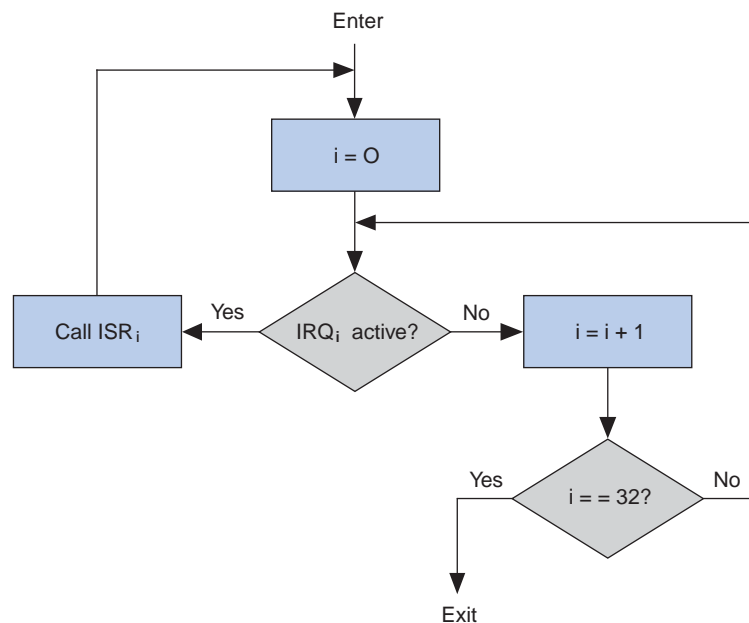
With the EIC interface, the Nios II processor supports a potentially unlimited number of hardware interrupts on daisy-chained EICs. The interrupt priority level can be software-configurable. Details of setting interrupt priorities depend on the particular EIC implementation. The hardware ensures that the highest-priority interrupt is always serviced first.

You register ISRs at system initialization time. Interrupt dispatch is handled by hardware.



For details, refer to [“Exception Handling System Structure”](#) on page 8-26.

**Figure 8-2.** HAL Hardware Interrupt Funnel for the Internal Interrupt Controller



The HAL provides the following interrupt funnels:

- Shadow register set, pre-emption disabled
- Shadow register set, pre-emption enabled
- Nonmaskable interrupt



For details, refer to [“Using Interrupt Funnels”](#) on page 8-12.

## Software Exception Funnel

Software exceptions can include unimplemented instructions, traps, and miscellaneous exceptions.

Software exception handling depends on options selected in the BSP. If you have enabled unimplemented instruction emulation, the software exception funnel first checks whether an unimplemented instruction caused the exception. If so, it emulates the instruction. Otherwise, it handles traps and miscellaneous exceptions.

## Unimplemented Instructions

You can include a handler to emulate unimplemented instructions. The Nios II processor architecture defines the following implementation-dependent instructions:

- `mul`
- `muli`
- `mulxss`
- `mulxsu`
- `mulxuu`
- `div`
- `divu`



For details about unimplemented instructions, refer to “Unimplemented Instructions” in the *Processor Architecture* chapter of the *Nios II Processor Reference Handbook*.



Unimplemented instructions are different from invalid instructions, which are described in “Invalid Instructions” on page 8-32.

## When to Use the Unimplemented Instruction Handler

You do not normally need the unimplemented instruction handler, because the HAL includes software emulation for unimplemented instructions from its run-time libraries if you are compiling for a Nios II processor that does not support the instructions.

You might need the unimplemented instruction handler under the following circumstances:

- You are running a Nios II program on an implementation of the Nios II processor other than the one you compiled for. The best solution is to build your program for the correct Nios II processor implementation. Only if this is not possible should you resort to the unimplemented instruction handler.
- You have assembly language code that uses an implementation-dependent instruction.

Figure 8-3 shows a flowchart of the HAL software exception funnel, including the optional instruction emulation logic. If instruction emulation is not enabled, this logic is omitted.

If unimplemented instruction emulation is disabled, but the processor encounters an unimplemented instruction, the software exception funnel treats the exception as a miscellaneous exception. Miscellaneous exceptions are described in “Miscellaneous Exceptions” on page 8-32.

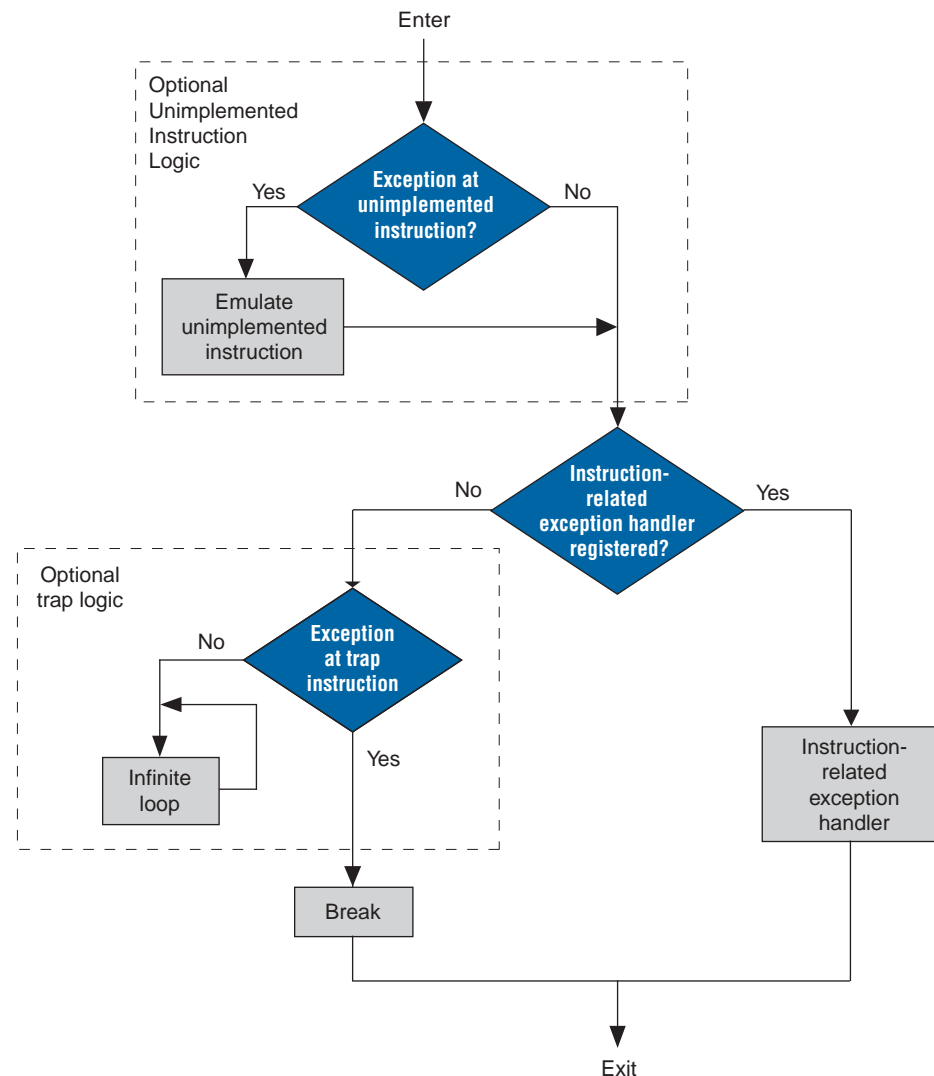
## Using the Unimplemented Instruction Handler

To include the unimplemented instruction handler, turn on the `hal.enable_mul_div_emulation` BSP property. The emulation routines occupy less than ¾ KBytes of memory.



An exception handler must never execute an unimplemented instruction. The HAL exception handling system does not support nested software exceptions.

**Figure 8-3.** HAL Software Exception Funnel



## Instruction-Related Exceptions

If the cause of the software exception is not an unimplemented instruction, the HAL software exception funnel checks for a registered instruction-related exception handler. If no instruction-related exception handler is registered, the exception is handled as described in [“Software Trap Handling”](#). If a handler is registered, the HAL software exception funnel calls it, then restores context and returns. Refer to [“The Instruction-Related Exception Handler”](#) for a description of the instruction-related exception handler and how to register it.

## Software Trap Handling

If no instruction-related exception handler is registered, the HAL software exception funnel checks for a trap instruction. If the exception is caused by a trap instruction, the trap exception handler executes a break instruction. The break instruction transfers control to a hardware debug core, if one is available. If the exception is not caused by a trap instruction, it is treated as a miscellaneous exception.

## Miscellaneous Exceptions

If the software exception is not caused by an unimplemented instruction or a trap, it is a miscellaneous exception.

If a debug core is present in the Nios II processor, traps and miscellaneous exceptions are handled identically, by executing a break instruction. Figure 8-3 shows a flowchart of the HAL software exception funnel, including the optional trap logic. If a debug core is present in the Nios II processor, the trap logic is omitted.

In a debugging environment, the processor executes a break, allowing the debugger to take control. In a nondebugging environment, the processor enters an infinite loop.



For details about the Nios II processor break instruction, refer to the *Programming Model* and *Instruction Set Reference* chapters of the *Nios II Processor Reference Handbook*.

Miscellaneous exceptions can occur for these reasons:

- Advanced exceptions, the memory protection unit (MPU), or the memory management unit (MMU) are implemented in the Nios II processor core. To handle advanced and MPU exceptions, refer to “*The Instruction-Related Exception Handler*”. To handle MMU exceptions, you need to implement a full-featured operating system, as mentioned in the *Programming Model* chapter of the *Nios II Processor Reference Handbook*.
- You need to include the unimplemented instruction handler, discussed in “*Unimplemented Instructions*” on page 8-30.
- A peripheral is generating spurious hardware interrupts. This is a symptom of a serious hardware problem. A peripheral might generate spurious hardware interrupts if it deasserts its interrupt output before an ISR has explicitly serviced it.

## Invalid Instructions

An invalid instruction word contains invalid codes in the OP or OPX field. For normal Nios II core implementations, the result of executing an invalid instruction is undefined; processor behavior is dependent on the Nios II core.

Therefore, the software exception funnel cannot detect or respond to an invalid instruction.



Invalid instructions are different from unimplemented instructions, which are described in “*Unimplemented Instructions*” on page 8-30.



For more information, refer to the *Nios II Core Implementation Details* chapter of the *Nios II Processor Reference Handbook*.

## The Instruction-Related Exception Handler

The software exception funnel lets you handle instruction-related exceptions, such as the advanced exceptions. The instruction-related exception handler is a custom handler. Your software registers the instruction-related exception handler with the HAL at startup time.





The `hal.enable_instruction_related_exceptions_api` setting must be enabled in the BSP in order for you to register an instruction-related exception handler.



For further information about the Nios II instruction-related exceptions, refer to the *Programming Model* chapter of the *Nios II Processor Reference Handbook*. For details about enabling instruction-related exception handlers, refer to “Settings” in the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer’s Handbook*.

When you register an instruction-related exception handler, it takes the place of the break/optional trap logic.

When you remove the instruction-related exception handler, the HAL restores the default break/optional trap logic.

## Writing an Instruction-Related Exception Handler

The prototype for an instruction-related exception handler is as follows:

```
alt_exception_result handler (  
    alt_exception_cause  cause,  
    alt_u32              addr,  
    alt_u32              bad_addr );
```

The instruction-related exception handler’s return value is a flag requesting that the HAL either re-execute the instruction, or skip it.

The HAL exception funnel calls the instruction-related exception handler with the following arguments:

- `cause`—A value representing the exception type, as shown in [Table 8-4](#)
- `addr`—Instruction address at which exception occurred
- `bad_addr`—Bad address register (if implemented)

Include the following header file in your instruction-related exception handler code:

```
#include "sys/alt_exceptions.h"
```

**alt\_exceptions.h** provides type macro definitions required to interface your instruction-related exception handler to the HAL, including the cause codes shown in [Table 8-4](#).

The API function `alt_exception_cause_generated_bad_addr()` is provided by the HAL, for the use of the instruction-related exception handler. This function parses the cause argument and determines if `bad_addr` contains the exception-causing address.



For further information about Nios II processor exception causes, refer to “Exception Processing” in the *Programming Model* chapter of the *Nios II Processor Reference Handbook*.

**Table 8-4.** Nios II Exception Cause Codes

Exception	Cause Code	Cause Symbol (1)
Reset	0	NIOS2_EXCEPTION_RESET
Processor-only Reset Request	1	NIOS2_EXCEPTION_CPU_ONLY_RESET_REQUEST
Hardware Interrupt	2	NIOS2_EXCEPTION_INTERRUPT
Trap Instruction	3	NIOS2_EXCEPTION_TRAP_INST
Unimplemented Instruction	4	NIOS2_EXCEPTION_UNIMPLEMENTED_INST
Illegal Instruction	5	NIOS2_EXCEPTION_ILLEGAL_INST
Misaligned Data Address	6	NIOS2_EXCEPTION_MISALIGNED_DATA_ADDR
Misaligned Destination Address	7	NIOS2_EXCEPTION_MISALIGNED_TARGET_PC
Division Error	8	NIOS2_EXCEPTION_DIVISION_ERROR
Supervisor-only Instruction Address	9	NIOS2_EXCEPTION_SUPERVISOR_ONLY_INST_ADDR
Supervisor-only Instruction	10	NIOS2_EXCEPTION_SUPERVISOR_ONLY_INST
Supervisor-only Data Address	11	NIOS2_EXCEPTION_SUPERVISOR_ONLY_DATA_ADDR
Translation lookaside buffer (TLB) Miss	12	NIOS2_EXCEPTION_TLB_MISS
TLB Permission Violation (execute)	13	NIOS2_EXCEPTION_TLB_EXECUTE_PERM_VIOLATION
TLB Permission Violation (read)	14	NIOS2_EXCEPTION_TLB_READ_PERM_VIOLATION
TLB Permission Violation (write)	15	NIOS2_EXCEPTION_TLB_WRITE_PERM_VIOLATION
MPU Region Violation (instruction)	16	NIOS2_EXCEPTION_MPU_INST_REGION_VIOLATION
MPU Region Violation (data)	17	NIOS2_EXCEPTION_MPU_DATA_REGION_VIOLATION
Cause unknown (2)	-1	NIOS2_EXCEPTION_CAUSE_NOT_PRESENT
<b>Notes to Table 8-4:</b> (1) Cause symbols are defined in <b>sys/alt_exceptions.h</b> . (2) This value is passed to the instruction-related exception handler if the <b>cause</b> argument if the cause is not known; for example, if the <b>cause</b> register not implemented in the Nios II processor core.		

If there is an instruction-related exception handler, it is called at the end of the software exception funnel (if the funnel has not recognized a hardware interrupt, unimplemented instruction or trap). It takes the place of the break or infinite loop. Therefore, to support debugging, execute a break on a trap instruction.



It is possible for an instruction-related exception to occur during execution of an ISR.

## Registering an Instruction-Related Exception Handler

The HAL API function `alt_instruction_exception_register()` registers a single instruction-related exception handler.

The function prototype is as follows:

```
alt_instruction_exception_register (
    alt_exception_result (*handler)
    ( alt_exception_cause, alt_u32, alt_u32 ));
```

The handler argument is a pointer to the instruction-related exception handler.

To use `alt_instruction_exception_register()`, include the following header file:

```
#include "sys/alt_exceptions.h"
```



The `hal.enable_instruction_related_exceptions_api` setting must be enabled in the BSP in order for you to register an instruction-related exception handler.



For details, refer to “Settings” in the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer’s Handbook*.



Register the instruction-related exception handler as early as possible in function `main()`. This allows you to handle abnormal condition during startup. You register an exception handler from the `alt_main()` function.



For more information about `alt_main()`, refer to “Boot Sequence and Entry Point” in the *Developing Programs Using the Hardware Abstraction Layer* chapter of the *Nios II Software Developer’s Handbook*.

## Removing an Instruction-Related Exception Handler

To remove a registered instruction-related exception handler, your C code must call the `alt_instruction_exception_register()` function, as follows:

```
alt_instruction_exception_register ( null, null );
```

When the HAL removes the instruction-related exception handler, it restores the default break/optional trap logic.

## Referenced Documents

This chapter references the following documents:

- *Developing Programs Using the Hardware Abstraction Layer* chapter of the *Nios II Software Developer’s Handbook*
- *Cache and Tightly-Coupled Memory* 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*
- *Processor Architecture* chapter of the *Nios II Processor Reference Handbook*
- *Programming Model* chapter of the *Nios II Processor Reference Handbook*
- *Instantiating the Nios II Processor in SOPC Builder* chapter of the *Nios II Processor Reference Handbook*
- *Nios II Core Implementation Details* chapter of the *Nios II Processor Reference Handbook*
- *Instruction Set Reference* chapter of the *Nios II Processor Reference Handbook*
- *Volume 5: Embedded Peripherals* of the *Quartus II Handbook*

- *Using Nios II Tightly Coupled Memory Tutorial*
- *AN595: Vectored Interrupt Controller Applications and Usage*

## Document Revision History

Table 8–5 shows the revision history for this document.

**Table 8–5.** Document Revision History (Part 1 of 2)

Date & Document Version	Changes Made	Summary of Changes
November 2009 9.1.0	<ul style="list-style-type: none"> <li>■ Described HAL support for external interrupt controller interface</li> <li>■ Described HAL support for shadow register sets with external interrupt controller interface</li> <li>■ Described enhanced HAL interrupt API</li> <li>■ Removed information specific to the Nios II IDE</li> </ul>	<ul style="list-style-type: none"> <li>■ External interrupt controller interface</li> <li>■ Enhanced HAL interrupt API</li> <li>■ Legacy HAL interrupt API deprecated</li> </ul>
March 2009 v9.0.0	<ul style="list-style-type: none"> <li>■ Reorganized and updated information and terminology to clarify role of Nios II Software Build Tools.</li> <li>■ Corrected minor typographical errors.</li> </ul>	
May 2008 v8.0.0	No change from previous release.	
October 2007 v7.2.0	No change from previous release.	
May 2007 v7.1.0	<ul style="list-style-type: none"> <li>■ Added table of contents to “Introduction” section.</li> <li>■ Added Referenced Documents section.</li> </ul>	
March 2007 v7.0.0	No change from previous release.	
November 2006 v6.1.0	<ul style="list-style-type: none"> <li>■ Describes support for the interrupt vector custom instruction.</li> </ul>	Interrupt vector custom instruction added.
May 2006 v6.0.0	<ul style="list-style-type: none"> <li>■ Corrected error in <code>alt_irq_enable_all()</code> usage</li> <li>■ Added illustrations</li> <li>■ Revised text on optimizing ISRs</li> <li>■ Expanded and revised text discussing HAL exception handler code structure.</li> </ul>	
October 2005 v5.1.0	<ul style="list-style-type: none"> <li>■ Updated references to HAL exception-handler assembly source files in section “HAL Exception Handler Files”.</li> <li>■ Added description of <code>alt_irq_disable()</code> and <code>alt_irq_enable()</code> in section “Interrupt Service Routines”.</li> </ul>	
May 2005 v5.0.0	Added tightly-coupled memory information.	
December 2004 v1.2	Corrected the “Registering the Button PIO ISR with the HAL” example.	

**Table 8-5.** Document Revision History (Part 2 of 2)

<b>Date &amp; Document Version</b>	<b>Changes Made</b>	<b>Summary of Changes</b>
September 2004 v1.1	<ul style="list-style-type: none"><li>■ Changed examples.</li><li>■ Added ISR performance data.</li></ul>	
May 2004 v1.0	Initial Release.	



## Introduction

Nios® II processor cores may contain instruction and data caches. This chapter discusses cache-related issues that you need to consider to guarantee that your program executes correctly on the Nios II processor. Fortunately, most software based on the Nios II hardware abstraction layer (HAL) works correctly without any special accommodations for caches. However, some software must manage the cache directly. For code that needs direct control over the cache, the Nios II architecture provides facilities to perform the following actions:

- Initialize lines in the instruction and data caches
- Flush lines in the instruction and data caches
- Bypass the data cache during load and store instructions

This chapter discusses the following common cases in which you must manage the cache:

- Initializing cache after reset
- Writing device drivers
- Writing program loaders or self-modifying code
- Managing cache in multi-master or multi-processor systems

This chapter contains the following sections:

- “Initializing Cache after Reset” on page 9-2
- “Writing Device Drivers” on page 9-4
- “Writing Program Loaders or Self-Modifying Code” on page 9-5
- “Managing Cache in Multi-Master/ Multi-Processor Systems” on page 9-5
- “Tightly-Coupled Memory” on page 9-7

## Nios II Cache Implementation

Depending on the Nios II core implementation, a Nios II processor system may or may not have data or instruction caches. You can write programs generically so that they function correctly on any Nios II processor, regardless of whether it has cache memory. For a Nios II core without one or both caches, cache management operations are benign and have no effect.

The current Nios II cores have no hardware cache coherency mechanism. Therefore, if multiple masters can access shared memory, software must explicitly maintain coherency across all masters.



For complete details about the features of each Nios II core implementation, refer to the *Nios II Core Implementation Details* chapter of the *Nios II Processor Reference Handbook*.

The details for a particular Nios II processor system are defined in the **system.h** file. **Example 9-1** shows an excerpt from the **system.h** file, defining the cache properties, such as cache size and the size of a single cache line.

**Example 9-1.** An Excerpt from system.h that Defines the Cache Structure

```
#define NIOS2_ICACHE_SIZE 4096
#define NIOS2_DCACHE_SIZE 0
#define NIOS2_ICACHE_LINE_SIZE 32
#define NIOS2_DCACHE_LINE_SIZE 0
```

This system has a 4 Kbyte instruction cache with 32 byte lines, and no data cache.

## HAL API Functions for Managing Cache

The HAL application program interface (API) provides the following functions for managing cache memory:

- `alt_dcache_flush()`
- `alt_dcache_flush_all()`
- `alt_icache_flush()`
- `alt_icache_flush_all()`
- `alt_uncached_malloc()`
- `alt_uncached_free()`
- `alt_remap_uncached()`
- `alt_remap_cached()`



For details about API functions, refer to the *HAL API Reference* chapter of the *Nios II Software Developer's Handbook*.

## Further Information

This chapter covers only cache management issues that affect Nios II programmers. It does not discuss the fundamental operation of caches. Refer to *The Cache Memory Book* by Jim Handy for a discussion of general cache management issues.

## Initializing Cache after Reset

After reset, the contents of the instruction cache and data cache are unknown. They must be initialized at the start of the software reset handler for correct operation.

The Nios II caches cannot be disabled by software; they are always enabled. To allow proper operation, a processor reset causes the instruction cache to invalidate the one instruction cache line that corresponds to the reset handler address. This forces the instruction cache to fetch instructions corresponding to this cache line from memory. The reset handler address must be aligned to the size of the instruction cache line.



It is the responsibility of the first eight instructions of the reset handler to initialize the remainder of the instruction cache. The Nios II `init_i` instruction initializes a single instruction cache line. Do not use the `flush_i` instruction because it may cause undesired effects when used to initialize the instruction cache in future Nios II implementations.

Place the `init_i` instruction in a loop that executes `init_i` for each instruction cache line address. [Example 9-2](#) shows an example of assembly code to initialize the instruction cache.

---

**Example 9-2.** Assembly Code to Initialize the Instruction Cache

---

```
mov     r4, r0
movhi   r5, %hi(NIOS2_ICACHE_SIZE)
ori     r5, r5, %lo(NIOS2_ICACHE_SIZE)
icache_init_loop:
init_i  r4
addi    r4, r4, NIOS2_ICACHE_LINE_SIZE
bltu    r4, r5, icache_init_loop
```

---

After the instruction cache is initialized, the data cache must also be initialized. The Nios II `init_d` instruction initializes a single data cache line. Do not use the `flush_d` instruction for this purpose, because it writes dirty lines back to memory. The data cache is undefined after reset, including the cache line tags. Using `flush_d` can cause unexpected writes of random data to random addresses. The `init_d` instruction does not write back dirty data.

Place the `init_d` instruction in a loop that executes `init_d` for each data cache line address. [Example 9-3](#) shows an example of assembly code to initialize the data cache:

---

**Example 9-3.** Assembly Code to Initialize the Data Cache

---

```
mov     r4, r0
movhi   r5, %hi(NIOS2_DCACHE_SIZE)
ori     r5, r5, %lo(NIOS2_DCACHE_SIZE)
dcache_init_loop:
init_d  0(r4)
addi    r4, r4, NIOS2_DCACHE_LINE_SIZE
bltu    r4, r5, dcache_init_loop
```

---

It is legal to execute instruction and data cache initialization code on Nios II cores that do not implement one or both of the caches. The `init_i` and `init_d` instructions are simply treated as `nop` instructions if there is no cache of the corresponding type present.

## For HAL Users

Programs based on the HAL need not manage the initialization of cache memory. The HAL C run-time code (`crt0.S`) provides a default reset handler that performs cache initialization before `alt_main()` or `main()` is called.

## Writing Device Drivers

Device drivers typically access control registers associated with their device. These registers are mapped into the Nios II address space. When accessing device registers, the data cache must be bypassed to ensure that accesses are not lost or deferred due to the data cache.

When writing a device driver, bypass the data cache with the `ldio/stio` family of instructions. On Nios II cores without a data cache, these instructions behave just like their corresponding `ld/st` instructions, and therefore are benign.



Declaring a C pointer `volatile` does not make pointer accesses bypass the data cache. The `volatile` keyword merely prevents the compiler from optimizing out accesses using the pointer. This `volatile` behavior is different from the methodology for the first-generation Nios processor.

### For HAL Users

The HAL provides the C-language macros `IORD` and `IOWR` that expand to the appropriate assembly instructions to bypass the data cache. The `IORD` macro expands to the `ldwio` instruction, and the `IOWR` macro expands to the `stwio` instruction. These macros should be used by HAL device drivers to access device registers.

Table 9-1 shows the available macros. All of these macros bypass the data cache when they perform their operation. In general, your program passes values defined in `system.h` as the `BASE` and `REGNUM` parameters. These macros are defined in the file `<Nios II EDS install path>/components/altera_nios2/HAL/inc/io.h`.

**Table 9-1.** HAL I/O Macros to Bypass the Data Cache

Macro	Use
<code>IORD(BASE, REGNUM)</code>	Read the value of the register at offset <code>REGNUM</code> in a device with base address <code>BASE</code> . Registers are assumed to be offset by the address width of the bus.
<code>IOWR(BASE, REGNUM, DATA)</code>	Write the value <code>DATA</code> to the register at offset <code>REGNUM</code> in a device with base address <code>BASE</code> . Registers are assumed to be offset by the address width of the bus.
<code>IORD_32DIRECT(BASE, OFFSET)</code>	Make a 32-bit read access at the location with address <code>BASE+OFFSET</code> .
<code>IORD_16DIRECT(BASE, OFFSET)</code>	Make a 16-bit read access at the location with address <code>BASE+OFFSET</code> .
<code>IORD_8DIRECT(BASE, OFFSET)</code>	Make an 8-bit read access at the location with address <code>BASE+OFFSET</code> .
<code>IOWR_32DIRECT(BASE, OFFSET, DATA)</code>	Make a 32-bit write access to write the value <code>DATA</code> at the location with address <code>BASE+OFFSET</code> .
<code>IOWR_16DIRECT(BASE, OFFSET, DATA)</code>	Make a 16-bit write access to write the value <code>DATA</code> at the location with address <code>BASE+OFFSET</code> .
<code>IOWR_8DIRECT(BASE, OFFSET, DATA)</code>	Make an 8-bit write access to write the value <code>DATA</code> at the location with address <code>BASE+OFFSET</code> .

## Writing Program Loaders or Self-Modifying Code

Software that writes instructions to memory, such as program loaders or self-modifying code, needs to ensure that old instructions are flushed from the instruction cache and processor pipeline. This flushing is accomplished with the `flushi` and `flushp` instructions, respectively. Additionally, if new instruction(s) are written to memory using store instructions that do not bypass the data cache, you must use the `flushd` instruction to flush the new instruction(s) from the data cache to memory.

Example 9-4 shows assembly code that writes a new instruction to memory.

### Example 9-4. Assembly Code That Writes a New Instruction to Memory

```
/*
 * Assume new instruction in r4 and
 * instruction address already in r5.
 */
stw    r4, 0(r5)
flushd 0(r5)
flushi  r5
flushp
```

The `stw` instruction writes the new instruction in `r4` to the instruction address specified by `r5`. If a data cache is present, the instruction is written just to the data cache and the associated line is marked dirty. The `flushd` instruction writes the data cache line associated with the address in `r5` to memory and invalidates the corresponding data cache line. The `flushi` instruction invalidates the instruction cache line associated with the address in `r5`. Finally, the `flushp` instruction ensures that the processor pipeline has not prefetched the old instruction at the address specified by `r5`.

Notice that Example 9-4 uses the `stw/flushd` pair instead of the `stwio` instruction. The `stwio` instruction does not flush the data cache, and therefore might leave stale data in the data cache.

This code sequence is correct for all Nios II implementations. If a Nios II core does not have a particular kind of cache, the corresponding flush instruction (`flushd` or `flushi`) is executed as a `nop`.

## For Users of the HAL

The HAL API does not provide functions for this cache management case.

## Managing Cache in Multi-Master/ Multi-Processor Systems

The Nios II architecture does not provide hardware cache coherency. Instead, software cache coherency must be provided when communicating through shared memory. The data cache contents of all processors accessing the shared memory must be managed by software to ensure that all masters read the most recent values and do not overwrite new data with stale data. This management is done by using the data cache flushing and bypassing facilities to move data between the shared memory and the data cache(s) as needed.

The `flushd` instruction ensures that the data cache and memory contain the same value for one line. If the line contains dirty data, it is written to memory. The line is then invalidated in the data cache.

Consistently bypassing the data cache is very important. The processor does not check if an address is in the data cache when bypassing the data cache. If software cannot guarantee that a particular address is in the data cache, it must flush the address from the data cache before bypassing it for a load or store. This action guarantees that the processor does not bypass new (dirty) data in the cache, and mistakenly access old data in memory.

## Bit-31 Cache Bypass

The `ldio/stio` family of instructions explicitly bypass the data cache. Bit-31 provides an alternate method to bypass the data cache. Using the bit-31 cache bypass, the normal `ld/st` family of instructions may be used to bypass the data cache if the most significant bit of the address (bit 31) is set to one. The value of bit 31 is only used internally to the processor; bit 31 is forced to zero in the actual address accessed. This limits the maximum byte address space to 31 bits.

Using bit 31 to bypass the data cache is a convenient mechanism for software because the cacheability of the associated address is contained in the address. This usage allows the address to be passed to code that uses the normal `ld/st` family of instructions, while still guaranteeing that all accesses to that address consistently bypass the data cache.

Bit-31 cache bypass is only explicitly provided in the Nios II/f core, and should not be used for other Nios II cores. The other Nios II cores that do not support bit-31 cache bypass limit their maximum byte address space to 31 bits to ease migration of code from one implementation to another. They effectively ignore the value of bit 31, which allows code written for a Nios II/f core using bit 31 cache bypass to run correctly on other current Nios II implementations. In general, this feature depends on the Nios II core implementation.



For details, refer to the *Nios II Core Implementation Details* chapter of the *Nios II Processor Reference Handbook*.

## For HAL Users

The HAL provides the C-language `IORD_*DIRECT` macros that expand to the `ldio` family of instructions and the `IOWR_*DIRECT` macros that expand to the `stio` family of instructions. Refer to [Table 9-1 on page 9-4](#). These macros are provided to access noncacheable memory regions.

The HAL provides the `alt_uncached_malloc()`, `alt_uncached_free()`, `alt_remap_uncached()`, and `alt_remap_cached()` routines to allocate and manipulate regions of uncached memory. These routines are available on Nios II cores with or without a data cache—code written for a Nios II core with a data cache is completely compatible with a Nios II core without a data cache.

The `alt_uncached_malloc()` and `alt_remap_uncached()` routines guarantee that the allocated memory region is not in the data cache and that all subsequent accesses to the allocated memory regions bypass the data cache.

## Tightly-Coupled Memory

If you want the performance of cache all the time, place your code or data in a tightly-coupled memory. Tightly-coupled memory is fast on-chip memory that bypasses the cache and has guaranteed low latency. Tightly-coupled memory gives the best memory access performance. You assign code and data to tightly-coupled memory partitions in the same way as other memory sections.

Cache instructions do not affect tightly-coupled memory. However, cache-management instructions become NOPs, which might result in unnecessary overhead.



For more information, refer to “Memory Usage” in the *Developing Programs Using the Hardware Abstraction Layer* chapter of the *Nios II Software Developer’s Handbook*.

## Referenced Documents

This chapter references the following documents:

- *Developing Programs Using the Hardware Abstraction Layer* chapter of the *Nios II Software Developer’s Handbook*
- *HAL API Reference* chapter of the *Nios II Software Developer’s Handbook*
- *Nios II Core Implementation Details* chapter of the *Nios II Processor Reference Handbook*

## Document Revision History

Table 9–2 shows the revision history for this document.

**Table 9–2.** Document Revision History (Part 1 of 2)

Date & Document Version	Changes Made	Summary of Changes
November 2009 v9.1.0	No change from previous release.	
March 2009 v9.0.0	<ul style="list-style-type: none"> <li>■ Reorganized and updated information and terminology to clarify role of Nios II Software Build Tools.</li> <li>■ Corrected minor typographical errors.</li> </ul>	
May 2008 v8.0.0	No change from previous release.	
October 2007 v7.2.0	No change from previous release.	
May 2007 v7.1.0	<ul style="list-style-type: none"> <li>■ Added table of contents to “Introduction” section.</li> <li>■ Added Referenced Documents section.</li> </ul>	
March 2007 v7.0.0	No change from previous release.	

**Table 9-2.** Document Revision History (Part 2 of 2)

<b>Date &amp; Document Version</b>	<b>Changes Made</b>	<b>Summary of Changes</b>
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	Added detail to section “ <b>Tightly-Coupled Memory</b> ”.	
May 2005 v5.0.0	Added tightly-coupled memory section.	
May 2004 v1.0	Initial Release.	

## Introduction

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

- “Overview” on page 10–1
- “Other RTOS Providers” on page 10–2
- “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, pre-emptive, 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](http://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](http://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.

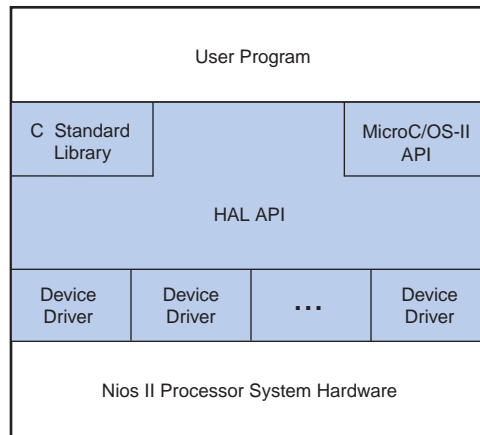
## MicroC/OS-II Architecture

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, 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 “Nios II Software Projects” in 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 with the Nios II Software Build Tools for Eclipse™, or on the Nios II command line.



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`.



For a list of available MicroC/OS-II BSP settings, refer to “Settings” in the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*. MicroC/OS-II settings are identified by the prefix `ucosii`. For information about how to configure MicroC/OS-II with BSP settings, refer to the *Getting Started with the Graphical User Interface*, *Nios II Software Build Tools*, and *Nios II Software Build Tools Reference* chapters of the *Nios II Software Developer's Handbook*. The meaning of each setting is defined fully in *MicroC/OS-II: The Real-Time Kernel*.

## Referenced Documents

This chapter references the following documents:

- *Getting Started with the Graphical User Interface* chapter of the *Nios II Software Developer's Handbook*
- *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 10-2 shows the revision history for this document.

**Table 10-2.** Document Revision History

Date & Document Version	Changes Made	Summary of Changes
November 2009 v9.1.0	<ul style="list-style-type: none"> <li>■ Remove tables of Nios II IDE-specific setting names. Refer solely to BSP setting names.</li> </ul>	<ul style="list-style-type: none"> <li>■ Introduced the Nios II Software Build Tools for Eclipse</li> </ul>
March 2009 v9.0.0	<ul style="list-style-type: none"> <li>■ Reorganized and updated information and terminology to clarify role of Nios II Software Build Tools.</li> <li>■ Corrected minor typographical errors.</li> </ul>	
May 2008 v8.0.0	No change from previous release.	
October 2007 v7.2.0	<ul style="list-style-type: none"> <li>■ Added documentation for MicroC/OS-II development with the Nios II Software Build Tools.</li> <li>■ Added description of HAL ISR support</li> </ul>	
May 2007 v7.1.0	<ul style="list-style-type: none"> <li>■ Added table of contents to "Introduction" section.</li> <li>■ Added Referenced Documents section.</li> </ul>	
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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.	



## Overview

The NicheStack® TCP/IP Stack - Nios® II Edition is a small-footprint implementation of the TCP/IP suite. The focus of the NicheStack TCP/IP Stack implementation is to reduce resource usage while providing a full-featured TCP/IP stack. The NicheStack TCP/IP Stack is designed for use in embedded systems with small memory footprints, making it suitable for Nios II processor systems.

Altera provides the NicheStack TCP/IP Stack as a software package that you can add to your board support package (BSP), available through the Nios II Software Build Tools. The NicheStack TCP/IP Stack includes these features:

- Internet Protocol (IP) including packet forwarding over multiple network interfaces
- Internet control message protocol (ICMP) for network maintenance and debugging
- User datagram protocol (UDP)
- Transmission Control Protocol (TCP) with congestion control, round trip time (RTT) estimation, and fast recovery and retransmit
- Dynamic host configuration protocol (DHCP)
- Address resolution protocol (ARP) for Ethernet
- Standard sockets application program interface (API)

This chapter discusses the details of how to use the NicheStack TCP/IP Stack for the Nios II processor only. This chapter contains the following sections:

- [“Prerequisites” on page 11–2](#)
- [“Introduction” on page 11–2](#)
- [“Other TCP/IP Stack Providers” on page 11–3](#)
- [“Using the NicheStack TCP/IP Stack” on page 11–3](#)
- [“Configuring the NicheStack TCP/IP Stack in a Nios II Program” on page 11–9](#)
- [“Further Information” on page 11–10](#)
- [“Known Limitations” on page 11–10](#)

## Prerequisites



To make the best use of information in this chapter, you should be familiar with these topics:

- Sockets. Several books are available on the topic of programming with sockets. Two good texts are *Unix Network Programming* by Richard Stevens and *Internetworking with TCP/IP Volume 3* by Douglas Comer.
- The Nios II Embedded Design Suite (EDS). Refer to the [Overview](#) chapter of the *Nios II Software Developer's Handbook* for more information about the Nios II EDS.
- The MicroC/OS-II RTOS. To learn about MicroC/OS-II, refer to the [MicroC/OS-II Real-Time Operating System](#) chapter of the *Nios II Software Developer's Handbook*, or to the [Using MicroC/OS-II RTOS with the Nios II Processor Tutorial](#).

## Introduction

Altera provides the Nios II implementation of the NicheStack TCP/IP Stack, including source code, in the Nios II EDS. The NicheStack TCP/IP Stack provides you with immediate access to a stack for Ethernet connectivity for the Nios II processor. The Altera implementation of the NicheStack TCP/IP Stack includes an API wrapper, providing the standard, well documented socket API.

The NicheStack TCP/IP Stack uses the MicroC/OS-II RTOS multithreaded environment. Therefore, to use the NicheStack TCP/IP Stack with the Nios II EDS, you must base your C/C++ project on the MicroC/OS-II RTOS. The Nios II processor system must also contain an Ethernet interface, or media access control (MAC). The Altera-provided NicheStack TCP/IP Stack includes driver support for the following two MACs:

- The SMSC lan91c111 device
- The Altera® Triple Speed Ethernet MegaCore® function

The Nios II Embedded Design Suite includes hardware for both MACs. The NicheStack TCP/IP Stack driver is interrupt-based, so you must ensure that interrupts for the Ethernet component are connected.

Altera's implementation of the NicheStack TCP/IP Stack is based on the hardware abstraction layer (HAL) generic Ethernet device model. In the generic device model, you can write a new driver to support any target Ethernet MAC, and maintain the consistent HAL and sockets API to access the hardware.



For details about writing an Ethernet device driver, refer to the [Developing Device Drivers for the Hardware Abstraction Layer](#) chapter of the *Nios II Software Developer's Handbook*.



## The NicheStack TCP/IP Stack Files and Directories

You need not edit the NicheStack TCP/IP Stack source code to use the stack in a Nios II C/C++ program. Nonetheless, Altera provides the source code for your reference. By default the files are installed with the Nios II EDS in the `<Nios II EDS install path>/components/altera_iniche/UCOSII` directory. For the sake of brevity, this chapter refers to this directory as `<iniche path>`.

Under `<iniche path>`, the original code is maintained—as much as possible—under the `<iniche path>/src/downloads` directory. This organization facilitates upgrading to more recent versions of the NicheStack TCP/IP Stack. The `<iniche path>/src/downloads/packages` directory contains the original NicheStack TCP/IP Stack source code and documentation; the `<iniche path>/src/downloads/30src` directory contains code specific to the Nios II implementation of the NicheStack TCP/IP Stack, including source code supporting MicroC/OS-II.



The reference manual for the NicheStack TCP/IP Stack is available on the [Literature: Nios II Processor](#) page of the Altera website, under **Other Related Documentation**.

Altera's implementation of the NicheStack TCP/IP Stack is based on version 3.1 of the protocol stack, with wrappers around the code to integrate it with the HAL.

## Licensing

The NicheStack TCP/IP Stack is a TCP/IP protocol stack created by InterNiche Technologies, Inc. You can license the NicheStack TCP/IP Stack from Altera by going to [the Altera website](#).



You can license other protocol stacks directly from InterNiche. You can obtain details from InterNiche Technologies, Inc. ([www.interniche.com](http://www.interniche.com))

## Other TCP/IP Stack Providers

Other third party vendors also provide Ethernet support for the Nios II processor. Notably, third party RTOS vendors often offer Ethernet modules for their particular RTOS frameworks.



For up-to-date information about products available from third party providers, visit the [Embedded Software](#) page of the Altera website.

## Using the NicheStack TCP/IP Stack

This section discusses how to include the NicheStack TCP/IP Stack in a Nios II program.

The primary interface to the NicheStack TCP/IP Stack is the standard sockets interface. In addition, you call the following functions to initialize the stack and drivers:

- `alt_iniche_init()`
- `netmain()`

You also use the global variable `iniche_net_ready` in the initialization process.

You must provide the following simple functions, which the HAL system code calls to obtain the MAC address and IP address:

- `get_mac_addr()`
- `get_ip_addr()`

## Nios II System Requirements

To use the NicheStack TCP/IP Stack, your Nios II system must meet the following requirements:

- The system hardware generated in SOPC Builder must include an Ethernet interface with interrupts enabled.
- The BSP must be based on MicroC/OS-II.
- The MicroC/OS-II RTOS must be configured to have the following settings:
  - TimeManagement / OSTimeTickHook must be enabled.
  - Maximum Number of Tasks must be 4 or higher.
- The system clock timer must be set to point to an appropriate timer device.

## The NicheStack TCP/IP Stack Tasks

The NicheStack TCP/IP Stack, in its standard Nios II configuration, consists of two fundamental tasks. Each of these tasks consumes a MicroC/OS-II thread resource, along with some memory for the thread's stack. In addition to the tasks your program creates, the following tasks run continuously:

- **The NicheStack main task**, `tk_netmain()`—After initialization, this task sleeps until a new packet is available for processing. Packets are received by an interrupt service routine (ISR). When the ISR receives a packet, it places it in the receive queue, and wakes up the main task.
- **The NicheStack tick task**, `tk_nettick()`—This task wakes up periodically to monitor for time-out conditions.

These tasks are started when the initialization process succeeds in the `netmain()` function, as described in “[netmain\(\)](#)”.



You can modify the task priority and stack sizes using `#define` statements in the configuration file **ippport.h**. You can create additional system tasks by enabling other options in the NicheStack TCP/IP Stack by editing **ippport.h**.

## Initializing the Stack

Before you initialize the stack, start the MicroC/OS-II scheduler by calling `OSStart()` from `main()`. Perform stack initialization in a high priority task, to ensure that your code does not attempt further initialization until the RTOS is running and I/O drivers are available.

To initialize the stack, call the functions `alt_iniche_init()` and `netmain()`. Global variable `iniche_net_ready` is set true when stack initialization is complete.



Ensure that your code does not use the sockets interface before `iniche_net_ready` is set to `true`. For example, call `alt_iniche_init()` and `netmain()` from the highest priority task, and wait for `iniche_net_ready` before allowing other tasks to run, as shown in [Example 11-1](#).

### **alt\_iniche\_init()**

`alt_iniche_init()` initializes the stack for use with the MicroC/OS-II operating system. The prototype for `alt_iniche_init()` is:

```
void alt_iniche_init(void)
```

`alt_iniche_init()` returns nothing and has no parameters.

### **netmain()**

`netmain()` is responsible for initializing and launching the NicheStack tasks. The prototype for `netmain()` is:

```
void netmain(void)
```

`netmain()` returns nothing and has no parameters.

### **iniche\_net\_ready**

When the NicheStack stack has completed initialization, it sets the global variable `iniche_net_ready` to a non-zero value.



Do not call any NicheStack API functions (other than for initialization) until `iniche_net_ready` is `true`.

[Example 11-1](#) illustrates the use of `iniche_net_ready` to wait until the network stack has completed initialization.

#### **Example 11-1. Instantiating the NicheStack TCP/IP Stack**

---

```
void SSSInitialTask(void *task_data)
{
    INT8U error_code;

    alt_iniche_init();
    netmain();

    while (!iniche_net_ready)
        TK_SLEEP(1);

    /* Now that the stack is running, perform the application
       initialization steps */

    .
    .
    .
}
```

---

Macro `TK_SLEEP()` is part of the NicheStack TCP/IP Stack operating system (OS) porting layer.

**get\_mac\_addr() and get\_ip\_addr()**

The NicheStack TCP/IP Stack system code calls `get_mac_addr()` and `get_ip_addr()` during the device initialization process. These functions are necessary for the system code to set the MAC and IP addresses for the network interface, which you select with the `altera_iniche.iniche_default_if` BSP setting. Because you write these functions yourself, your system has the flexibility to store the MAC address and IP address in an arbitrary location, rather than a fixed location hard-coded in the device driver. For example, some systems might store the MAC address in flash memory, while others might have the MAC address in on-chip embedded memory.

Both functions take as parameters device structures used internally by the NicheStack TCP/IP Stack. However, you do not need to know the details of the structures. You only need to know enough to fill in the MAC and IP addresses.

The prototype for `get_mac_addr()` is:

```
int get_mac_addr(NET net, unsigned char mac_addr[6]);
```

You must implement the `get_mac_addr()` function to assign the MAC address to the `mac_addr` argument. Leave the `net` argument untouched.

The prototype for `get_mac_addr()` is in the header file `<iniche path>/inc/alt_iniche_dev.h`. The `NET` structure is defined in the `<iniche path>/src/downloads/30src/h/net.h` file.

**Example 11-2** shows an implementation of `get_mac_addr()`. For demonstration purposes only, the MAC address is stored at address `CUSTOM_MAC_ADDR` in this example. There is no error checking in this example. In a real application, if there is an error, `get_mac_addr()` must return -1.

**Example 11-2. An Implementation of get\_mac\_addr()**


---

```
#include <alt_iniche_dev.h>
#include "includes.h"
#include "ipport.h"
#include "tcpport.h"
#include <io.h>
int get_mac_addr(NET net, unsigned char mac_addr[6])
{
    int ret_code = -1;

    /* Read the 6-byte MAC address from wherever it is stored */
    mac_addr[0] = IORD_8DIRECT(CUSTOM_MAC_ADDR, 4);
    mac_addr[1] = IORD_8DIRECT(CUSTOM_MAC_ADDR, 5);
    mac_addr[2] = IORD_8DIRECT(CUSTOM_MAC_ADDR, 6);
    mac_addr[3] = IORD_8DIRECT(CUSTOM_MAC_ADDR, 7);
    mac_addr[4] = IORD_8DIRECT(CUSTOM_MAC_ADDR, 8);
    mac_addr[5] = IORD_8DIRECT(CUSTOM_MAC_ADDR, 9);
    ret_code = ERR_OK;

    return ret_code;
}
```

---

You must write the function `get_ip_addr()` to assign the IP address of the protocol stack. Your program can either assign a static address, or request the DHCP to find an IP address. The function prototype for `get_ip_addr()` is:

```
int get_ip_addr(alt_iniche_dev* p_dev,
               ip_addr*      ipaddr,
               ip_addr*      netmask,
               ip_addr*      gw,
               int*          use_dhcp);
```

`get_ip_addr()` sets the return parameters as follows:

```
IP4_ADDR(&ipaddr, IPADDR0, IPADDR1, IPADDR2, IPADDR3);
IP4_ADDR(&gw, GWADDR0, GWADDR1, GWADDR2, GWADDR3);
IP4_ADDR(&netmask, MSKADDR0, MSKADDR1, MSKADDR2, MSKADDR3);
```

For the dummy variables `IP_ADDR0-3`, substitute expressions for bytes 0-3 of the IP address. For `GWADDR0-3`, substitute the bytes of the gateway address. For `MSKADDR0-3`, substitute the bytes of the network mask. For example, the following statement sets `ip_addr` to IP address 137.57.136.2:

```
IP4_ADDR ( ip_addr, 137, 57, 136, 2 );
```

To enable DHCP, include the line:

```
*use_dhcp = 1;
```

The NicheStack TCP/IP stack attempts to get an IP address from the server. If the server does not provide an IP address within 30 seconds, the stack times out and uses the default settings specified in the `IP4_ADDR()` function calls.

To assign a static IP address, include the lines:

```
*use_dhcp = 0;
```

The prototype for `get_ip_addr()` is in the header file `<iniche path>/inc/alt_iniche_dev.h`.

**Example 11-3** shows an implementation of `get_ip_addr()` and shows a list of the necessary include files.



There is no error checking in **Example 11-3**. In a real application, you might need to return -1 on error.

`INICHE_DEFAULT_IF`, defined in **system.h**, identifies the network interface that you defined in SOPC Builder. You can control `INICHE_DEFAULT_IF` through the `iniche_default_if` BSP setting.

`DHCP_CLIENT`, also defined in **system.h**, specifies whether to use the DHCP client application to obtain an IP address. You can set or clear this property with the `altera_iniche.dhcp_client` setting.

## Calling the Sockets Interface

After you initialize your Ethernet device, use the sockets API in the remainder of your program to access the IP stack.

To create a new task that talks to the IP stack using the sockets API, you must use the function `TK_NEWTASK()`. The `TK_NEWTASK()` function is part of the NicheStack TCP/IP Stack operating system (OS) porting layer. `TK_NEWTASK()` calls the MicroC/OS-II `OSTaskCreate()` function to create a thread, and performs some other actions specific to the NicheStack TCP/IP Stack.

The prototype for `TK_NEWTASK()` is:

```
int TK_NEWTASK(struct inet_task_info* nettask);
```

### Example 11-3. An Implementation of `get_ip_addr()`

---

```
#include <alt_iniche_dev.h>
#include "includes.h"
#include "ipport.h"
#include "tcpport.h"
int get_ip_addr(alt_iniche_dev* p_dev,
               ip_addr* ipaddr,
               ip_addr* netmask,
               ip_addr* gw,
               int*      use_dhcp)
{
    int ret_code = -1;
    /*
     * The name here is the device name defined in system.h
     */
    if (!strcmp(p_dev->name, "/dev/" INICHE_DEFAULT_IF))
    {
        /* The following is the default IP address if DHCP
         fails, or the static IP address if DHCP_CLIENT is
         undefined. */
        IP4_ADDR(&ipaddr, 10, 1, 1, 3);
        /* Assign the Default Gateway Address */
        IP4_ADDR(&gw, 10, 1, 1, 254);
        /* Assign the Netmask */
        IP4_ADDR(&netmask, 255, 255, 255, 0);

#ifdef DHCP_CLIENT
        *use_dhcp = 1;
#else
        *use_dhcp = 0;
#endif /* DHCP_CLIENT */

        ret_code = ERR_OK;
    }
    return ret_code;
}
```

---

The prototype is defined in `<iniche path>/src/downloads/30src/nios2/osport.h`. You can include this header file as follows:

```
#include "osport.h"
```

You can find other details of the OS porting layer in the `osport.c` file in the NicheStack TCP/IP Stack component directory, `<iniche path>/src/downloads/30src/nios2/`.



For more information about how to use `TK_NEWTASK()` in an application, refer to the [Using the NicheStack TCP/IP Stack - Nios II Edition Tutorial](#).

## Configuring the NicheStack TCP/IP Stack in a Nios II Program

The NicheStack TCP/IP Stack has many options that you can configure using `#define` directives in the file `ippport.h`. The Nios II EDS allows you to configure certain options (that is, modify the `#defines` in `system.h`) without editing source code. The most commonly accessed options are available through a set of BSP options, identifiable by the prefix `altera_iniche`.



For further information about BSP settings for the NicheStack, refer to the *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*.

Some less-frequently-used options are not accessible through the BSP settings. If you need to modify these options, you must edit the `ippport.h` file manually.

You can find `ippport.h` in the `debug/system_description` directory for your BSP project.

The following sections describe the features that you can configure using the Nios II Software Build Tools. Both development flows provide a default value for each feature. In general, these values provide a good starting point, and you can later fine-tune the values to meet the needs of your system.

### NicheStack TCP/IP Stack General Settings

The ARP, UDP, and IP protocols are always enabled. [Table 11-1](#) shows the protocol options.

**Table 11-1.** Protocol Options

Option	Description
TCP	Enables and disables the TCP.

[Table 11-2](#) shows the global options, which affect the overall behavior of the TCP/IP stack.

**Table 11-2.** Global Options

Option	Description
Use DHCP to automatically assign IP address	If this option is turned on, the component uses DHCP to acquire an IP address. If this option is turned off, you must assign a static IP address.
Enable statistics	If this option is turned on, the stack keeps counters of packets received, errors, etc. The counters are defined in <code>mib</code> structures defined in various header files in directory <code>&lt;iniche path&gt;/src/downloads/30src/h</code> . For details about <code>mib</code> structures, refer to the NicheStack documentation.
MAC interface	If the IP stack has more than one network interface, this parameter indicates which interface to use. Refer to <a href="#">“Known Limitations” on page 11-10</a> .

## IP Options

Table 11-3 shows the IP options.

**Table 11-3.** IP Options

Option	Description
Forward IP packets	If there is more than one network interface, this option is turned on, and the IP stack for one interface receives packets that are not addressed to it, the stack forwards the packet out of the other interface. Refer to <a href="#">“Known Limitations” on page 11-10</a> .
Reassemble IP packet fragments	If this option is turned on, the NicheStack TCP/IP Stack reassembles IP packet fragments as full IP packets. Otherwise, it discards IP packet fragments. This topic is explained in <i>Unix Network Programming</i> by Richard Stevens.

## TCP Options

Table 11-4 shows the TCP zero copy option, which is only available if the TCP option is turned on.

**Table 11-4.** TCP Options

Option	Description
Use TCP zero copy	This option enables the NicheStack zero copy TCP API. This option allows you to eliminate buffer-to-buffer copies when using the NicheStack TCP/IP Stack. For details, refer to the NicheStack reference manual. You must modify your application code to take advantage of the zero copy API.

## Further Information

For further information about the Altera NicheStack implementation, refer to the [Using the NicheStack TCP/IP Stack - Nios II Edition Tutorial](#). The tutorial provides in-depth information about the NicheStack TCP/IP Stack, and illustrates how to use it in a networking application.



For details about NicheStack, refer to the NicheStack TCP/IP Stack reference manual, available on the [Literature: Nios II Processor](#) page of the Altera website, under **Other Related Documentation**.

## Known Limitations

Although the NicheStack code contains features intended to support multiple network interfaces, these features are not tested in the Nios II edition. Refer to the NicheStack TCP/IP Stack reference manual and source code for information about multiple network interface support.



## Referenced Documents

This chapter references the following documents:

- *Overview* 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*
- *MicroC/OS-II Real-Time Operating System* chapter of the *Nios II Software Developer's Handbook*
- *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*
- NicheStack TCP/IP Stack reference manual, available on the [Literature: Nios II Processor](#) page of the Altera website, under **Other Related Documentation**
- *Using the NicheStack TCP/IP Stack - Nios II Edition Tutorial*
- *Using MicroC/OS-II RTOS with the Nios II Processor Tutorial*

## Document Revision History

Table 11-5 shows the revision history for this document.

**Table 11-5.** Document Revision History

Date and Document Version	Changes Made	Summary of Changes
November 2009 v9.1.0	<ul style="list-style-type: none"> <li>■ Nios II IDE information removed to <i>Appendix A. Using the Nios II Integrated Development Environment</i>.</li> </ul>	Introduced the Nios II Software Build Tools for Eclipse™
March 2009 v9.0.0	<ul style="list-style-type: none"> <li>■ Reorganized and updated information and terminology to clarify role of Nios II Software Build Tools.</li> <li>■ Corrected minor typographical errors.</li> </ul>	
May 2008 v8.0.0	No change from previous release.	
October 2007 v7.2.0	No change from previous release.	
May 2007 v7.1.0	<ul style="list-style-type: none"> <li>■ Minor clarifications added to content.</li> <li>■ Added table of contents to Overview section.</li> <li>■ Added Referenced Documents section.</li> </ul>	
March 2007 v7.0.0	No change from previous release.	
November 2006 v6.1.0	Initial Release.	



## Introduction

Altera provides a read-only zip file system for use with the hardware abstraction layer (HAL). The read-only zip file system provides access to a simple file system stored in flash memory. The drivers take advantage of the HAL generic device driver framework for file subsystems. Therefore, you can access the zip file subsystem using the ANSI C standard library I/O functions, such as `fopen()` and `fread()`.

The Altera® read-only zip file system is provided as a software package. All source and header files for the HAL drivers are located in the directory `<Nios II EDS install path>/components/altera_ro_zipfs/HAL/`.

## Using the Zip File System in a Project

The read-only zip file system is supported by both Nios® II software development flows. You need not edit any source code to include and configure the file system. To use the zip file system, you use the Nios II development tools to include it as a software package for the board support package (BSP) project.

You must specify the following four parameters to configure the file system:

- The name of the flash device where you wish to program the file system.
- The offset in the address space of this flash device.
- The name of the mount point for this file subsystem in the HAL file system. For example, if you name the mount point `/mnt/zipfs`, the following code opens a file in the zip file:

```
fopen("/mnt/zipfs/hello", "r");
```

This code, called from within a HAL-based program, opens the file **hello** for reading.

- The name of the zip file you wish to use.

The next time you build your project after you make these settings, the Nios II development tools include and link the file subsystem in the project. After you rebuild the project, the **system.h** file reflects the presence of this software package in the system.

## Preparing the Zip File

The zip file must be uncompressed. The Altera read-only zip file system uses the zip format only for bundling files together; it does not provide the file decompression features for which zip utilities are known.

Creating a zip file with no compression is straightforward using the WinZip GUI. Alternately, use the `-e0` option to disable compression when using either `winzip` or `pkzip` from a command line.

## Programming the Zip File to Flash

For your program to access files in the zip file subsystem, you must first program the zip data to flash. As part of the project build process, the Nios II development tools create a Motorola S-record file (**.flash**) that includes the data for the zip file system.

You then use the Nios II Flash Programmer to program the zip file system data to flash memory on the board.



For details about programming flash, refer to the *Nios II Flash Programmer User Guide*.

## Referenced Documents

This chapter references the following document:

*Nios II Flash Programmer User Guide*

## Document Revision History

Table 12-1 shows the revision history for this document.

**Table 12-1.** Document Revision History (Part 1 of 2)

Date & Document Version	Changes Made	Summary of Changes
November 2009 v9.1.0	No change from previous release.	
March 2009 v9.0.0	<ul style="list-style-type: none"> <li>Reorganized and updated information and terminology to clarify role of Nios II Software Build Tools.</li> <li>Corrected minor typographical errors.</li> </ul>	
May 2008 v8.0.0	No change from previous release.	
October 2007 v7.2.0	No change from previous release.	
May 2007 v7.1.0	<ul style="list-style-type: none"> <li>Added table of contents to “Introduction” section.</li> <li>Added Referenced Documents section.</li> </ul>	
March 2007 v7.0.0	No change from previous release.	
November 2006 v6.1.0	No change from previous release.	
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**Table 12–1.** Document Revision History (Part 2 of 2)

<b>Date &amp; Document Version</b>	<b>Changes Made</b>	<b>Summary of Changes</b>
May 2005 v5.0.0	No change from previous release.	
May 2004 v1.0	Initial Release.	

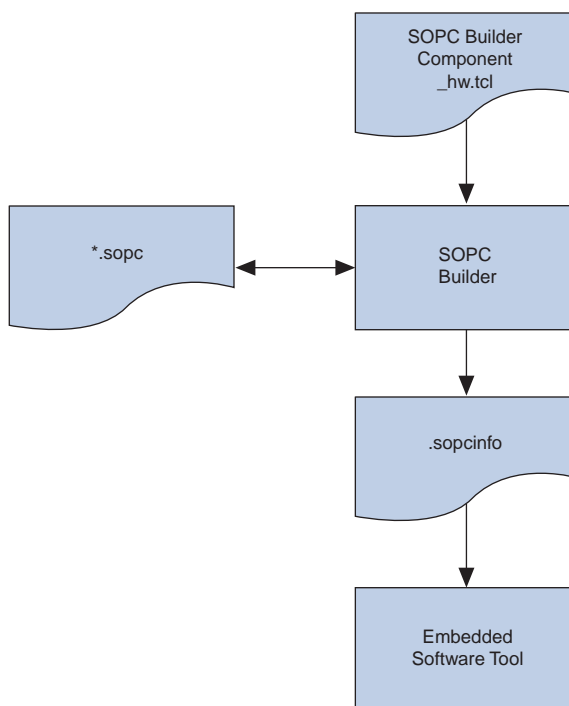


This document describes how to publish SOPC Builder component information for embedded software tools. You can publish component information for use by software, such as a C compiler and a board support package (BSP) generator. Information used by a C compiler might be a set of `#define` statements that describe some aspect of a component. Information used by a BSP generator might be the identification of memory components, so that the BSP generator can create a linker script.

## Component Information Flow

Figure 13–1 shows the flow of information from SOPC Builder components to embedded software tools.

**Figure 13–1.** Component Information Flow



A component publishes information by including Tcl assignment statements in its component description file, `<component_name>_hw.tcl`. Each assignment is a name-value pair that can be associated with the entire component, or with a single interface. When the assignment statement applies to the entire component, it is set using the `set_module_assignment` command. Assignment statements that apply to an interface are set using the `set_interface_assignment` command.

Example 13–1 shows the syntax for these assignment statements.

**Example 13-1. Syntax of Assignment Statements**


---

```
# These assignments apply to the entire component
# This is the syntax for the set_module_assignment command:
#   set_module_assignment <assignment_name> <value>

# Here are 3 examples
set_module_assignment embeddedsw.CMacro.colorSpace "CMYK"
set_module_assignment embeddedsw.configuration.cpuArchitecture "My processor"
set_module_assignment embeddedsw.memoryInfo.IS_FLASH 1

# This is the syntax of the set_interface_assignment command:
#   set_interface_assignment <interface_name> <assignment_name> <value>

# Here is an example
set_interface_assignment lcd0 embeddedsw.configuration.isPrintableDevice 1
```

---



For more information about the `_hw.tcl` file and using Tcl to define SOPC Builder components, refer to the *Component Interface Tcl Reference* chapter in *Volume 4: SOPC Builder of the Quartus® II Handbook*.

When you generate an SOPC Builder system, SOPC Builder creates an `<sopc_builder_system>.sopcinfo` file that includes all of the assignments for your component. The embedded software tools use these assignments for further processing. SOPC Builder does not require any of the information included in these assignments to build the hardware representation of the component. SOPC Builder simply passes the assignments from the `_hw.tcl` file to the SOPC Information File (`.sopcinfo`).

## Embedded Software Assignments

Embedded software assignments are organized in a period-separated namespace. All of the assignments for embedded software tools have the prefix `embeddedsw`. The `embeddedsw` namespace is further divided into the following three sub-namespaces:

- C Macro—Assignment name prefix `embeddedsw.CMacro`
- Configuration—Assignment name prefix `embeddedsw.configuration`
- Memory Initialization—Assignment name prefix `embeddedsw.memoryInfo`

### C Macro Namespace

You can use the C macro namespace to publish information about your component that is converted to `#define`'s in a C or C++ `system.h` file. C macro assignments are associated with the entire SOPC Builder component, not with individual interfaces.

The name of an assignment in the C macro namespace is `embeddedsw.CMacro.<assignmentName>`. You must format the value as a legal C or C++ expression.

Example [Example 13-2](#) illustrates a Tcl assignment statement for the `BAUD_RATE` of `uart_0` in an SOPC Builder system.



### Example 13-2. C Macro Example

```
# Tcl assignment statement included in the _hw.tcl file
add_parameter BAUD_RATE_PARAM integer 9600 "This is the default baud rate."

# Dynamically reassign the baud rate based on the parameter value
set_module_assignment embeddedsw.CMacro.BAUD_RATE \
    [get_parameter_value BAUD_RATE_PARAM]
```

Example 13-3 illustrates the corresponding C or C++ #define. The string BAUD\_RATE is appended to the name of the component. This #define is included in the system.h file.

### Example 13-3. Generated Macro in system.h

```
/* Generated macro in the system.h file after dynamic reassignment */
#define UART_0_BAUD_RATE 15200
```

Table 13-1 provides examples of how to format constants for 32-bit processors using the GNU Compiler Collection (GCC) C/C++ compiler.



For complete details on formatting constants, refer to the [GNU web page](#).

**Table 13-1.** GCC C/C++ 32-bit Processor Constants

C Data Type	Examples
boolean (char, short, int)	1, 0
32-bit signed integer (int, long)	123, -50
32-bit unsigned integer (unsigned int, unsigned long)	123u, 0xef8472a0
64-bit signed integer (long long int)	4294967296LL, -4294967296LL
64-bit unsigned integer (unsigned long long int)	4294967296ULL, 0xac458701fd64ULL
32-bit floating-point (float)	3.14f
64-bit floating-point (double)	2.78, 314e-2
character (char)	'x'
string (const char*)	"Hello World!"

## Configuration Namespace

You can use the configuration namespace to pass configuration information to embedded software tools. You can associate configuration namespace assignments with the entire component or with single interface.

The assignment name for the configuration namespace is embeddedsw.configuration.<name>. Altera embedded software tools already have definitions for the data types of the configuration names listed in this section.

Table 13-2 shows how to format configuration assignment values based on defined data types.

**Table 13-2.** Configuration Data Types

Configuration Data Type	Format
boolean	1, 0
32-bit integer	123, -50
64-bit integer	4294967296, -4294967296
32-bit floating-point	3.14
64-bit floating-point	2.78, 314e-2
string	ABC

Table 13-3 includes the embedded software configuration names that apply to the entire component.

**Table 13-3.** Component Configuration Information - Assign with `set_module_assignment`

Configuration Name	Type	Meaning	Example
<code>cpuArchitecture</code>	string	Processor instruction set architecture. Provide this assignment if you want your component to be considered a processor.	My 8051

Table 13-4 includes the embedded software configuration names that apply to an Avalon Memory-Mapped® (Avalon-MM) slave interface. All of these assignments are optional.

**Table 13-4.** Memory-Mapped Slave Information - Assign with `set_interface_assignment` (Part 1 of 2)

Configuration Name	Type	Default	Meaning	Examples
<code>isMemoryDevice</code>	boolean	0	The slave port provides access to a memory device.	Altera® On-Chip Memory Component, DDR Controller, erasable programmable configurable serial (EPCS) Controller
<code>isPrintableDevice</code>	boolean	0	The slave port provides access to a character-based device.	Altera UART, Altera JTAG UART, Altera LCD
<code>isTimerDevice</code>	boolean	0	The slave port provides access to a timer device.	Altera Timer
<code>isEthernetMacDevice</code>	boolean	0	The slave port provides access to an Ethernet media access control (MAC).	Altera Triple-Speed Ethernet

**Table 13–4.** Memory-Mapped Slave Information - Assign with `set_interface_assignment` (Part 2 of 2)

Configuration Name	Type	Default	Meaning	Examples
<code>isNonVolatileStorage</code> (1)	boolean	0	The memory device is a non-volatile memory device. The contents of a non-volatile memory device are fixed and always present. In normal operation, you can only read from this memory. If this property is true, you must also set <code>isMemoryDevice</code> to true.	Common flash interface (CFI) Flash, EPCS Flash, on-chip FPGA memory configured as a ROM
<code>isFlash</code>	boolean	0	The memory device is a flash memory device. If <code>isFlash</code> is true, you must also set <code>isMemoryDevice</code> and <code>isNonVolatileStorage</code> to true.	CFI Flash, EPCS Flash
<code>hideDevice</code>	boolean	0	Do not make this slave port visible to the embedded software tools.	Nios® II debug slave port
<code>affectsTransactionsOnMasters</code>	string	empty string	<p>A list of master names delimited by spaces, for example <code>m1 m2</code>. Used when the slave port provides access to Avalon-MM control registers in the component. The control registers control transfers on the specified master ports.</p> <p>The slave port can configure the control registers for master ports on the listed components. The address space for this slave port is composed of the address spaces of the named master ports.</p> <p>Nios II embedded software tools use this information to generate <code>#define</code> directives describing the address space of these master ports.</p>	Altera direct memory access (DMA), Altera Scatter/Gather DMA

**Note to Table 13–4:**

- (1) Some FPGA RAMs support initialization at power-up from the SRAM Object File (`.sof`) or programmer object file (`.pof`), but are not considered non-volatile because this ability might not be used.

Table 13–5 includes the embedded software configuration names that apply to an Avalon Streaming® (Avalon-ST) slave interface. All of these assignments are optional.

**Table 13-5.** Streaming Source Information - Assign with `set_interface_assignment`

Configuration Name	Type	Default	Meaning	Examples
<code>isInterruptControllerSender (1)</code>	boolean	0	The interface sends interrupts to an interrupt controller receiver interface.	Altera Vectored Interrupt Controller
<code>transportsInterruptsFromReceivers (2)</code>	string	empty string	A list of interrupt receiver interface names delimited by spaces. Used when the interrupt controller sender interface can transport daisy-chained interrupts from one or more interrupt controller receiver ports on the same module.	Altera Vectored Interrupt Controller daisy-chain input

**Note to Table 13-5:**

- (1) An interrupt sender interface is an Avalon-ST source providing interrupt information according to the external interrupt controller (EIC) protocol.
- (2) An interrupt receiver interface is an Avalon-ST sink receiving interrupt information from an EIC.

Table 13-6 includes the embedded software configuration names that apply to an Avalon-ST sink interface. All of these assignments are optional.

**Table 13-6.** Streaming Sink Information - Assign with `set_interface_assignment`

Configuration Name	Type	Default	Meaning	Examples
<code>isInterruptControllerReceiver (1)</code>	boolean	0	The interface receives interrupts (optionally daisy-chained) from an interrupt controller sender interface.	Altera Vectored Interrupt Controller, Altera Nios II

**Note to Table 13-6:**

- (1) An interrupt receiver interface is an Avalon-ST sink receiving interrupt information from an EIC.

## Memory Initialization Namespace

You use the memory initialization namespace to pass memory initialization information to embedded software tools. Use this namespace to create memory initialization files, including `.flash`, `.hex`, `.dat`, and `.sym` files. You use memory initialization files for the following tasks:

- Flash programming
- RTL simulation
- Creating initialized FPGA RAMs for Quartus II compilation

You only need to provide these assignments if your component is a memory device that you want to initialize.

The assignment name for the memory initialization namespace is `embeddedsw.memoryInfo.<name>`. Altera embedded software tools already have definitions for the data types of the possible values. Table 13-7 shows how to format memory initialization assignment values for all defined data types.

**Table 13-7.** Memory Initialization Data Types

Memory Initialization Data Type	Format
boolean	1, 0
32-bit integer	123, -50
string (1)	ABC

**Note to Table 13-7:**

(1) Quotation marks are not required.

Memory initialization assignments are associated with an entire component.

Table 13-8 shows the embedded software memory initialization names.

**Table 13-8.** Memory Initialization Information - Assign with set\_module\_assignment Command

Memory Initialization Name	Type	Default	Meaning
HAS_BYTE_LANE	boolean	0	Create a memory initialization file for each byte.
IS_FLASH	boolean	0	Component is a flash device.
IS_EPCS	boolean	0	If IS_FLASH and IS_EPCS are both 1, component is an EPCS flash device. If IS_FLASH is 1 and IS_EPCS is 0, the component is a CFI flash device. If IS_EPCS is 1, IS_FLASH must also be 1.
GENERATE_HEX	boolean	0	Create an Intel hexadecimal file (.hex).
GENERATE_DAT_SYM	boolean	0	Create a .dat and a .sym file.
GENERATE_FLASH	boolean	0	Create a Motorola S-record File (.flash).
INCLUDE_WARNING_MSG	string	empty string	Display a warning message when creating memory initialization files.
MEM_INIT_FILENAME	string	Module instance name	Name of the memory initialization file, without any file type suffix.
MEM_INIT_DATA_WIDTH	32-bit integer	none (mandatory)	Width of memory initialization file in bits. May be different than the slave port data width.

## Referenced Documents

This chapter references the following document:

*Component Interface Tcl Reference* chapter in *Volume 4: SOPC Builder of the Quartus II Handbook*

## Document Revision History

Table 13-9 shows the revision history for this document.

**Table 13-9.** Document Revision History

<b>Date &amp; Document Version</b>	<b>Changes Made</b>	<b>Summary of Changes</b>
November 2009 v9.1.0	Add the following Avalon-ST interface settings, to support external interrupt controllers: <ul style="list-style-type: none"><li>■ <code>embeddedsw.configuration.isInterruptControllerReceiver</code></li><li>■ <code>embeddedsw.configuration.isInterruptControllerSender</code></li><li>■ <code>embeddedsw.configuration.transportsInterruptsFromReceivers</code></li></ul>	External interrupt controller support
March 2009 v9.0.0	Initial Release.	

This section provides a comprehensive reference to the Nios® II hardware abstraction layer (HAL) application program interface (API) and the utilities, scripts, and settings that constitute the Nios II Software Build Tools. This section includes the following chapters:

- [Chapter 14, HAL API Reference](#)
- [Chapter 15, Nios II Software Build Tools Reference](#)
- [Appendix A, Using the Nios II Integrated Development Environment](#)





## Introduction

This chapter provides an alphabetically ordered list of all the functions in the hardware abstraction layer (HAL) application program interface (API). Each function is listed with its C prototype and a short description. Each listing provides information about whether the function is thread-safe when running in a multi-threaded environment, and whether it can be called from an interrupt service routine (ISR).

This chapter only lists the functionality provided by the HAL. You should be aware that the complete newlib API is also available from within HAL systems. For example, newlib provides `printf()`, and other standard I/O functions, which are not described here.




For more details about the newlib API, refer to the newlib documentation. On the Windows **Start** menu, click **Programs > Altera > Nios II > Nios II Documentation**.

## HAL API Functions

The HAL API functions are shown on the following pages.

## **`_exit()`**

Prototype:	<code>void _exit (int exit_code)</code>
Commonly called by:	Newlib C library
Thread-safe:	Yes.
Available from ISR:	No.
Include:	<code>&lt;unistd.h&gt;</code>
Description:	<p>The newlib <code>exit()</code> function calls the <code>_exit()</code> function to terminate the current process. Typically, <code>exit()</code> calls this function when <code>main()</code> completes. Because there is only a single process in HAL systems, the HAL implementation blocks forever.</p> <p> Interrupts are not disabled, so ISRs continue to execute.</p> <p>The input argument, <code>exit_code</code>, is ignored.</p>
Return:	—
See also:	Newlib documentation

## **`_rename()`**

Prototype:	<code>int _rename(char *existing, char* new)</code>
Commonly called by:	Newlib C library
Thread-safe:	Yes.
Available from ISR:	Yes.
Include:	<code>&lt;stdio.h&gt;</code>
Description:	The <code>_rename()</code> function is provided for newlib compatibility.
Return:	It always fails with return code <code>-1</code> , and with <code>errno</code> set to <code>ENOSYS</code> .
See also:	Newlib documentation

## alt\_alarm\_start()

Prototype:	<pre>int alt_alarm_start ( alt_alarm* alarm,   alt_u32      nticks,   alt_u32      (*callback) (void* context),   void*        context )</pre>
Commonly called by:	C/C++ programs Device drivers
Thread-safe:	Yes.
Available from ISR:	Yes.
Include:	<sys/alt_alarm.h>
Description:	<p>The <code>alt_alarm_start()</code> function schedules an alarm callback. Refer to “Using Timer Devices” in the <i>Developing Programs Using the Hardware Abstraction Layer</i> chapter of the <i>Nios® II Software Developer's Handbook</i>. The HAL waits <code>ntick</code> system clock ticks before calling the <code>callback()</code> function. When the HAL calls <code>callback()</code>, it passes it the input argument <code>context</code>.</p> <p>The <code>alarm</code> argument is a pointer to a structure that represents this alarm. You must create it, and it must have a lifetime that is at least as long as that of the alarm. However, you are not responsible for initializing the contents of the structure pointed to by <code>alarm</code>. This action is done by the call to <code>alt_alarm_start()</code>.</p>
Return:	The return value for <code>alt_alarm_start()</code> is zero on success, and negative otherwise. This function fails if there is no system clock available.
See also:	<pre>alt_alarm_stop() alt_nticks() alt_sysclk_init() alt_tick() alt_ticks_per_second() gettimeofday() settimeofday() times() usleep()</pre>

## alt\_alarm\_stop()

Prototype:	<code>void alt_alarm_stop (alt_alarm* alarm)</code>
Commonly called by:	C/C++ programs Device drivers
Thread-safe:	Yes.
Available from ISR:	Yes.
Include:	<code>&lt;sys/alt_alarm.h&gt;</code>
Description:	<p>You can call the <code>alt_alarm_stop()</code> function to cancel an alarm previously registered by a call to <code>alt_alarm_start()</code>. The input argument is a pointer to the alarm structure in the previous call to <code>alt_alarm_start()</code>.</p> <p>On return the alarm is canceled, if it is still active.</p>
Return:	–
See also:	<code>alt_alarm_start()</code> <code>alt_nticks()</code> <code>alt_sysclk_init()</code> <code>alt_tick()</code> <code>alt_ticks_per_second()</code> <code>gettimeofday()</code> <code>settimeofday()</code> <code>times()</code> <code>usleep()</code>

## alt\_dcache\_flush()

Prototype:	<code>void alt_dcache_flush (void* start, alt_u32 len)</code>
Commonly called by:	C/C++ programs Device drivers
Thread-safe:	Yes.
Available from ISR:	Yes.
Include:	<code>&lt;sys/alt_cache.h&gt;</code>
Description:	<p>The <code>alt_dcache_flush()</code> function flushes the data cache for a memory region of length <code>len</code> bytes, starting at address <code>start</code>. Flushing the cache consists of writing back dirty data and then invalidating the cache.</p> <p>In processors without data caches, it has no effect.</p>
Return:	—
See also:	<code>alt_dcache_flush_all()</code> <code>alt_icache_flush()</code> <code>alt_icache_flush_all()</code> <code>alt_remap_cached()</code> <code>alt_remap_uncached()</code> <code>alt_uncached_free()</code> <code>alt_uncached_malloc()</code>

## **alt\_dcache\_flush\_all()**

Prototype:	<code>void alt_dcache_flush_all (void)</code>
Commonly called by:	C/C++ programs Device drivers
Thread-safe:	Yes.
Available from ISR:	Yes.
Include:	<code>&lt;sys/alt_cache.h&gt;</code>
Description:	<p>The <code>alt_dcache_flush_all()</code> function flushes, that is, writes back dirty data and then invalidates, the entire contents of the data cache.</p> <p>In processors without data caches, it has no effect.</p>
Return:	—
See also:	<code>alt_dcache_flush()</code> <code>alt_icache_flush()</code> <code>alt_icache_flush_all()</code> <code>alt_remap_cached()</code> <code>alt_remap_uncached()</code> <code>alt_uncached_free()</code> <code>alt_uncached_malloc()</code>

## alt\_dev\_reg()

Prototype:	<code>int alt_dev_reg(alt_dev* dev)</code>
Commonly called by:	Device drivers
Thread-safe:	No.
Available from ISR:	No.
Include:	<code>&lt;sys/alt_dev.h&gt;</code>
Description:	<p>The <code>alt_dev_reg()</code> function registers a device with the system. After it is registered, you can access a device using the standard I/O functions. Refer to the <i>Developing Programs Using the Hardware Abstraction Layer</i> chapter of the <i>Nios II Software Developer's Handbook</i>.</p> <p>The system behavior is undefined in the event that a device is registered with a name that conflicts with an existing device or file system.</p> <p>The <code>alt_dev_reg()</code> function is not thread-safe in the sense that there should be no other thread using the device list at the time that <code>alt_dev_reg()</code> is called. Call <code>alt_dev_reg()</code> only in the following circumstances:</p> <ul style="list-style-type: none"><li>■ When running in single-threaded mode.</li><li>■ From a device initialization function called by <code>alt_sys_init()</code>. <code>alt_sys_init()</code> should only be called by the single-threaded C startup code.</li></ul>
Return:	The return value is zero upon success. A negative return value indicates failure.
See also:	<code>alt_fs_reg()</code>



## alt\_dma\_rxchan\_close()

Prototype:	<code>int alt_dma_rxchan_close (alt_dma_rxchan rxchan)</code>
Commonly called by:	C/C++ programs Device drivers
Thread-safe:	Yes.
Available from ISR:	No.
Include:	<code>&lt;sys/alt_dma.h&gt;</code>
Description:	The <code>alt_dma_rxchan_close()</code> function notifies the system that the application has finished using the direct memory access (DMA) receive channel, <code>rxchan</code> . The current implementation always succeeds.
Return:	The return value is zero on success and negative otherwise.
See also:	<code>alt_dma_rxchan_depth()</code> <code>alt_dma_rxchan_ioctl()</code> <code>alt_dma_rxchan_open()</code> <code>alt_dma_rxchan_prepare()</code> <code>alt_dma_rxchan_reg()</code> <code>alt_dma_txchan_close()</code> <code>alt_dma_txchan_ioctl()</code> <code>alt_dma_txchan_open()</code> <code>alt_dma_txchan_reg()</code> <code>alt_dma_txchan_send()</code> <code>alt_dma_txchan_space()</code>

## alt\_dma\_rxchan\_depth()

Prototype:	<code>alt_u32 alt_dma_rxchan_depth(alt_dma_rxchan dma)</code>
Commonly called by:	C/C++ programs Device drivers
Thread-safe:	Yes.
Available from ISR:	No.
Include:	<code>&lt;sys/alt_dma.h&gt;</code>
Description:	<p>The <code>alt_dma_rxchan_depth()</code> function returns the maximum number of receive requests that can be posted to the specified DMA transmit channel, <code>dma</code>.</p> <p>Whether this function is thread-safe, or can be called from an ISR, depends on the underlying device driver. In general it should be assumed this is not the case.</p>
Return:	Returns the maximum number of receive requests that can be posted.
See also:	<code>alt_dma_rxchan_close()</code> <code>alt_dma_rxchan_ioctl()</code> <code>alt_dma_rxchan_open()</code> <code>alt_dma_rxchan_prepare()</code> <code>alt_dma_rxchan_reg()</code> <code>alt_dma_txchan_close()</code> <code>alt_dma_txchan_ioctl()</code> <code>alt_dma_txchan_open()</code> <code>alt_dma_txchan_reg()</code> <code>alt_dma_txchan_send()</code> <code>alt_dma_txchan_space()</code>

## alt\_dma\_rxchan\_ioctl()

Prototype: `int alt_dma_rxchan_ioctl (alt_dma_rxchan dma,  
int req,  
void* arg)`

Commonly called by: C/C++ programs

Device drivers

Thread-safe: See description.

Available from ISR: See description.

Include: `<sys/alt_dma.h>`

Description: The `alt_dma_rxchan_ioctl()` function performs DMA I/O operations on the DMA receive channel, `dma`. The I/O operations are device specific. For example, some DMA drivers support options to control the width of the transfer operations. The input argument, `req`, is an enumeration of the requested operation; `arg` is an additional argument for the request. The interpretation of `arg` is request dependent.

[Table 14-1](#) shows generic requests defined in `alt_dma.h`, which a DMA device might support.

Whether a call to `alt_dma_rxchan_ioctl()` is thread-safe, or can be called from an ISR, is device dependent. In general it should be assumed it is not the case.

Do not call the `alt_dma_rxchan_ioctl()` function while DMA transfers are pending, or unpredictable behavior could result.

For device-specific information about the Altera® DMA controller core, refer to the [DMA Controller Core](#) chapter in *Volume 5: Embedded Peripherals of the Quartus® II Handbook*.

Return: A negative return value indicates failure. The interpretation of nonnegative return values is request specific.

See also:

- `alt_dma_rxchan_close()`
- `alt_dma_rxchan_depth()`
- `alt_dma_rxchan_open()`
- `alt_dma_rxchan_prepare()`
- `alt_dma_rxchan_reg()`
- `alt_dma_txchan_close()`
- `alt_dma_txchan_ioctl()`
- `alt_dma_txchan_open()`
- `alt_dma_txchan_reg()`
- `alt_dma_txchan_send()`
- `alt_dma_txchan_space()`

**Table 14–1.** Generic Requests

Request	Meaning
ALT_DMA_SET_MODE_8	Transfer data in units of 8 bits. The value of <code>arg</code> is ignored.
ALT_DMA_SET_MODE_16	Transfer data in units of 16 bits. The value of <code>arg</code> is ignored.
ALT_DMA_SET_MODE_32	Transfer data in units of 32 bits. The value of <code>arg</code> is ignored.
ALT_DMA_SET_MODE_64	Transfer data in units of 64 bits. The value of <code>arg</code> is ignored.
ALT_DMA_SET_MODE_128	Transfer data in units of 128 bits. The value of <code>arg</code> is ignored.
ALT_DMA_GET_MODE	Return the transfer width. The value of <code>arg</code> is ignored.
ALT_DMA_TX_ONLY_ON (1)	The ALT_DMA_TX_ONLY_ON request causes a DMA channel to operate in a mode in which only the transmitter is under software control. The other side writes continuously from a single location. The address to which to write is the argument to this request.
ALT_DMA_TX_ONLY_OFF (1)	Return to the default mode, in which both the receive and transmit sides of the DMA can be under software control.
ALT_DMA_RX_ONLY_ON (1)	The ALT_DMA_RX_ONLY_ON request causes a DMA channel to operate in a mode in which only the receiver is under software control. The other side reads continuously from a single location. The address to read is the argument to this request.
ALT_DMA_RX_ONLY_OFF (1)	Return to the default mode, in which both the receive and transmit sides of the DMA can be under software control.

**Note to Table 14–1:**

- (1) These macro names changed in version 1.1 of the Nios II Embedded Design Suite (EDS). The old names (ALT\_DMA\_TX\_STREAM\_ON, ALT\_DMA\_TX\_STREAM\_OFF, ALT\_DMA\_RX\_STREAM\_ON, and ALT\_DMA\_RX\_STREAM\_OFF) are still valid, but new designs should use the new names.

## alt\_dma\_rxchan\_open()

Prototype:	<code>alt_dma_rxchan alt_dma_rxchan_open (const char* name)</code>
Commonly called by:	C/C++ programs Device drivers
Thread-safe:	Yes.
Available from ISR:	No.
Include:	<code>&lt;sys/alt_dma.h&gt;</code>
Description:	The <code>alt_dma_rxchan_open()</code> function obtains an <code>alt_dma_rxchan</code> descriptor for a DMA receive channel. The input argument, <code>name</code> , is the name of the associated physical device, for example, <code>/dev/dma_0</code> .
Return:	The return value is null on failure and non-null otherwise. If an error occurs, <code>errno</code> is set to <code>ENODEV</code> .
See also:	<code>alt_dma_rxchan_close()</code> <code>alt_dma_rxchan_depth()</code> <code>alt_dma_rxchan_ioctl()</code> <code>alt_dma_rxchan_prepare()</code> <code>alt_dma_rxchan_reg()</code> <code>alt_dma_txchan_close()</code> <code>alt_dma_txchan_ioctl()</code> <code>alt_dma_txchan_open()</code> <code>alt_dma_txchan_reg()</code> <code>alt_dma_txchan_send()</code> <code>alt_dma_txchan_space()</code>

## alt\_dma\_rxchan\_prepare()

Prototype:	<pre>int alt_dma_rxchan_prepare (alt_dma_rxchan dma,                            void* data,                            alt_u32 length,                            alt_rxchan_done* done,                            void* handle)</pre>
Commonly called by:	C/C++ programs Device drivers
Thread-safe:	See description.
Available from ISR:	See description.
Include:	<sys/alt_dma.h>
Description:	<p>The <code>alt_dma_rxchan_prepare()</code> posts a receive request to a DMA receive channel. The input arguments are: <code>dma</code>, the channel to use; <code>data</code>, a pointer to the location that data is to be received to; <code>length</code>, the maximum length of the data to receive in bytes; <code>done</code>, callback function that is called after the data is received; <code>handle</code>, an opaque value passed to <code>done</code>.</p> <p>Whether this function is thread-safe, or can be called from an ISR, depends on the underlying device driver. In general it should be assumed it is not the case.</p>
Return:	The return value is zero upon success. A negative return value indicates that the request cannot be posted.
See also:	<pre>alt_dma_rxchan_close() alt_dma_rxchan_depth() alt_dma_rxchan_ioctl() alt_dma_rxchan_open() alt_dma_rxchan_reg() alt_dma_txchan_close() alt_dma_txchan_ioctl() alt_dma_txchan_open() alt_dma_txchan_reg() alt_dma_txchan_send() alt_dma_txchan_space()</pre>

## alt\_dma\_rxchan\_reg()

Prototype: `int alt_dma_rxchan_reg (alt_dma_rxchan_dev* dev)`

Commonly called by: C/C++ programs

Device drivers

Thread-safe: No.

Available from ISR: No.

Include: `<sys/alt_dma_dev.h>`

Description: The `alt_dma_rxchan_reg()` function registers a DMA receive channel with the system. After it is registered, a device can be accessed using the functions described in “Using DMA Devices” in the *Developing Programs Using the Hardware Abstraction Layer* chapter of the *Nios II Software Developer's Handbook*.

System behavior is undefined in the event that a channel is registered with a name that conflicts with an existing channel.

The `alt_dma_rxchan_reg()` function is not thread-safe if other threads are using the channel list at the time that `alt_dma_rxchan_reg()` is called. Call `alt_dma_rxchan_reg()` only in the following circumstances:

- When running in single-threaded mode.
- From a device initialization function called by `alt_sys_init().alt_sys_init()` should only be called by the single-threaded C startup code.

Return: The return value is zero upon success. A negative return value indicates failure.

See also:

```
alt_dma_rxchan_close()  
alt_dma_rxchan_depth()  
alt_dma_rxchan_ioctl()  
alt_dma_rxchan_open()  
alt_dma_rxchan_prepare()  
alt_dma_txchan_close()  
alt_dma_txchan_ioctl()  
alt_dma_txchan_open()  
alt_dma_txchan_reg()  
alt_dma_txchan_send()  
alt_dma_txchan_space()
```

## alt\_dma\_txchan\_close()

Prototype:	<code>int alt_dma_txchan_close (alt_dma_txchan txchan)</code>
Commonly called by:	C/C++ programs Device drivers
Thread-safe:	Yes.
Available from ISR:	No.
Include:	<code>&lt;sys/alt_dma.h&gt;</code>
Description:	The <code>alt_dma_txchan_close</code> function notifies the system that the application has finished using the DMA transmit channel, <code>txchan</code> . The current implementation always succeeds.
Return:	The return value is zero on success and negative otherwise.
See also:	<code>alt_dma_rxchan_close()</code> <code>alt_dma_rxchan_depth()</code> <code>alt_dma_rxchan_ioctl()</code> <code>alt_dma_rxchan_open()</code> <code>alt_dma_rxchan_prepare()</code> <code>alt_dma_rxchan_reg()</code> <code>alt_dma_txchan_ioctl()</code> <code>alt_dma_txchan_open()</code> <code>alt_dma_txchan_reg()</code> <code>alt_dma_txchan_send()</code> <code>alt_dma_txchan_space()</code>



## alt\_dma\_txchan\_ioctl()

Prototype: `int alt_dma_txchan_ioctl (alt_dma_txchan dma,  
int req,  
void* arg)`

Commonly called by: C/C++ programs

Device drivers

Thread-safe: See description.

Available from ISR: See description.

Include: `<sys/alt_dma.h>`

Description: The `alt_dma_txchan_ioctl()` function performs device specific I/O operations on the DMA transmit channel, `dma`. For example, some drivers support options to control the width of the transfer operations. The input argument, `req`, is an enumeration of the requested operation; `arg` is an additional argument for the request. The interpretation of `arg` is request dependent.

Refer to [Table 14-1 on page 14-12](#) for the generic requests a device might support.

Whether a call to `alt_dma_txchan_ioctl()` is thread-safe, or can be called from an ISR, is device dependent. In general it should be assumed this is not the case.

Do not call the `alt_dma_txchan_ioctl()` function while DMA transfers are pending, or unpredictable behavior could result.

Return: A negative return value indicates failure; otherwise the interpretation of the return value is request specific.

See also:

- `alt_dma_rxchan_close()`
- `alt_dma_rxchan_depth()`
- `alt_dma_rxchan_ioctl()`
- `alt_dma_rxchan_open()`
- `alt_dma_rxchan_prepare()`
- `alt_dma_rxchan_reg()`
- `alt_dma_txchan_close()`
- `alt_dma_txchan_open()`
- `alt_dma_txchan_reg()`
- `alt_dma_txchan_send()`
- `alt_dma_txchan_space()`

## alt\_dma\_txchan\_open()

Prototype:	<code>alt_dma_txchan alt_dma_txchan_open (const char* name)</code>
Commonly called by:	C/C++ programs Device drivers
Thread-safe:	Yes.
Available from ISR:	No.
Include:	<code>&lt;sys/alt_dma.h&gt;</code>
Description:	The <code>alt_dma_txchan_open()</code> function obtains an <code>alt_dma_txchan()</code> descriptor for a DMA transmit channel. The input argument, <code>name</code> , is the name of the associated physical device, for example, <code>/dev/dma_0</code> .
Return:	The return value is null on failure and non-null otherwise. If an error occurs, <code>errno</code> is set to <code>ENODEV</code> .
See also:	<code>alt_dma_rxchan_close()</code> <code>alt_dma_rxchan_depth()</code> <code>alt_dma_rxchan_ioctl()</code> <code>alt_dma_rxchan_open()</code> <code>alt_dma_rxchan_prepare()</code> <code>alt_dma_rxchan_reg()</code> <code>alt_dma_txchan_close()</code> <code>alt_dma_txchan_ioctl()</code> <code>alt_dma_txchan_reg()</code> <code>alt_dma_txchan_send()</code> <code>alt_dma_txchan_space()</code>

## alt\_dma\_txchan\_reg()

Prototype: `int alt_dma_txchan_reg (alt_dma_txchan_dev* dev)`

Commonly called by: C/C++ programs

Device drivers

Thread-safe: No.

Available from ISR: No.

Include: `<sys/alt_dma_dev.h>`

Description: The `alt_dma_txchan_reg()` function registers a DMA transmit channel with the system. After it is registered, a device can be accessed using the functions described in “Using DMA Devices” in the *Developing Programs Using the Hardware Abstraction Layer* chapter of the *Nios II Software Developer's Handbook*.

System behavior is undefined in the event that a channel is registered with a name that conflicts with an existing channel.

The `alt_dma_txchan_reg()` function is not thread-safe if other threads are using the channel list at the time that `alt_dma_txchan_reg()` is called. Call `alt_dma_txchan_reg()` only in the following circumstances:

- When running in single-threaded mode.
- From a device initialization function called by `alt_sys_init().alt_sys_init()` should only be called by the single-threaded C startup code.

Return: The return value is zero upon success. A negative return value indicates failure.

See also:

```
alt_dma_rxchan_close()  
alt_dma_rxchan_depth()  
alt_dma_rxchan_ioctl()  
alt_dma_rxchan_open()  
alt_dma_rxchan_prepare()  
alt_dma_rxchan_reg()  
alt_dma_txchan_close()  
alt_dma_txchan_ioctl()  
alt_dma_txchan_open()  
alt_dma_txchan_send()  
alt_dma_txchan_space()
```

## alt\_dma\_txchan\_send()

Prototype:                    `int alt_dma_txchan_send (alt_dma_txchan dma, const void* from, alt_u32 length, alt_txchan_done* done, void* handle)`

Commonly called by:        C/C++ programs

Device drivers

Thread-safe:                See description.

Available from ISR:        See description.

Include:                    `<sys/alt_dma.h>`

Description:                The `alt_dma_txchan_send()` function posts a transmit request to a DMA transmit channel. The input arguments are: `dma`, the channel to use; `from`, a pointer to the start of the data to send; `length`, the length of the data to send in bytes; `done`, a callback function that is called after the data is sent; and `handle`, an opaque value passed to `done`.

Whether this function is thread-safe, or can be called from an ISR, depends on the underlying device driver. In general it should be assumed this is not the case.

Return:                     The return value is negative if the request cannot be posted, and zero otherwise.

See also:

```
alt_dma_rxchan_close()
alt_dma_rxchan_depth()
alt_dma_rxchan_ioctl()
alt_dma_rxchan_open()
alt_dma_rxchan_prepare()
alt_dma_rxchan_reg()
alt_dma_txchan_close()
alt_dma_txchan_ioctl()
alt_dma_txchan_open()
alt_dma_txchan_reg()
alt_dma_txchan_space()
```

## alt\_dma\_txchan\_space()

Prototype: `int alt_dma_txchan_space (alt_dma_txchan dma)`

Commonly called by: C/C++ programs

Device drivers

Thread-safe: See description.

Available from ISR: See description.

Include: `<sys/alt_dma.h>`

Description: The `alt_dma_txchan_space()` function returns the number of transmit requests that can be posted to the specified DMA transmit channel, `dma`. A negative value indicates that the value cannot be determined.

Whether this function is thread-safe, or can be called from an ISR, depends on the underlying device driver. In general it should be assumed this is not the case.

Return: Returns the number of transmit requests that can be posted.

See also:

```
alt_dma_rxchan_close()  
alt_dma_rxchan_depth()  
alt_dma_rxchan_ioctl()  
alt_dma_rxchan_open()  
alt_dma_rxchan_prepare()  
alt_dma_rxchan_reg()  
alt_dma_txchan_close()  
alt_dma_txchan_ioctl()  
alt_dma_txchan_open()  
alt_dma_txchan_reg()  
alt_dma_txchan_send()
```

## alt\_erase\_flash\_block()

Prototype:	<pre>int alt_erase_flash_block(alt_flash_fd* fd,                            int          offset,                            int          length)</pre>
Commonly called by:	C/C++ programs Device drivers
Thread-safe:	No.
Available from ISR:	No.
Include:	<code>&lt;sys/alt_flash.h&gt;</code>
Description:	<p>The <code>alt_erase_flash_block()</code> function erases an individual flash erase block. The parameter <code>fd</code> specifies the flash device; <code>offset</code> is the offset within the flash of the block to erase; <code>length</code> is the size of the block to erase. No error checking is performed to check that this is a valid block, or that the length is correct. Refer to “Using Flash Devices” in the <i>Developing Programs Using the Hardware Abstraction Layer</i> chapter of the <i>Nios II Software Developer's Handbook</i>.</p> <p>Call the <code>alt_erase_flash_block()</code> function only when operating in single-threaded mode.</p> <p>The only valid values for the <code>fd</code> parameter are those returned from the <code>alt_flash_open_dev</code> function. If any other value is passed, the behavior of this function is undefined.</p>
Return:	The return value is zero upon success. A negative return value indicates failure.
See also:	<code>alt_flash_close_dev()</code> <code>alt_flash_open_dev()</code> <code>alt_get_flash_info()</code> <code>alt_read_flash()</code> <code>alt_write_flash()</code> <code>alt_write_flash_block()</code>

## **alt\_exception\_cause\_generated\_bad\_addr()**

Prototype: `int alt_exception_cause_generated_bad_addr  
( alt_exception_cause cause)`

Commonly called by: Instruction-related exception handlers

Thread-safe:

Available from ISR:

Include: `<sys/alt_exceptions.h>`

Description: This function validates the `bad_addr` argument to an instruction-related exception handler. The function parses the handler's `cause` argument to determine whether the `bad_addr` register contains the exception-causing address.

If the exception is of a type that generates a valid address in `bad_addr`, this function returns a nonzero value. Otherwise, it returns zero.

If the `cause` register is unimplemented in the Nios II processor core, this function always returns zero.

Return: A nonzero value means `bad_addr` contains the exception-causing address.

Zero means the value of `bad_addr` is to be ignored.

See also: `alt_instruction_exception_register()`

## alt\_flash\_close\_dev()

Prototype: `void alt_flash_close_dev(alt_flash_fd* fd)`

Commonly called by: C/C++ programs

Device drivers

Thread-safe: No.

Available from ISR: No.

Include: `<sys/alt_flash.h>`

Description: The `alt_flash_close_dev()` function closes a flash device. All subsequent calls to `alt_write_flash()`, `alt_read_flash()`, `alt_get_flash_info()`, `alt_erase_flash_block()`, or `alt_write_flash_block()` for this flash device fail.

Call the `alt_flash_close_dev()` function only when operating in single-threaded mode.

The only valid values for the `fd` parameter are those returned from the `alt_flash_open_dev` function. If any other value is passed, the behavior of this function is undefined.

Return: —

See also:

- `alt_erase_flash_block()`
- `alt_flash_open_dev()`
- `alt_get_flash_info()`
- `alt_read_flash()`
- `alt_write_flash()`
- `alt_write_flash_block()`



## alt\_flash\_open\_dev()

Prototype:	<code>alt_flash_fd* alt_flash_open_dev(const char* name)</code>
Commonly called by:	C/C++ programs Device drivers
Thread-safe:	No.
Available from ISR:	No.
Include:	<code>&lt;sys/alt_flash.h&gt;</code>
Description:	<p>The <code>alt_flash_open_dev()</code> function opens a flash device. After it is opened, you can perform the following operations:</p> <ul style="list-style-type: none"><li>■ Write to a flash device using <code>alt_write_flash()</code></li><li>■ Read from a flash device using <code>alt_read_flash()</code></li><li>■ Control individual flash blocks using <code>alt_get_flash_info()</code>, <code>alt_erase_flash_block()</code>, or <code>alt_write_flash_block()</code>.</li></ul> <p>Call the <code>alt_flash_open_dev</code> function only when operating in single-threaded mode.</p>
Return:	The return value is zero upon failure. Any other value indicates success.
See also:	<code>alt_erase_flash_block()</code> <code>alt_flash_close_dev()</code> <code>alt_get_flash_info()</code> <code>alt_read_flash()</code> <code>alt_write_flash()</code> <code>alt_write_flash_block()</code>


## alt\_fs\_reg()

Prototype:	<code>int alt_fs_reg (alt_dev* dev)</code>
Commonly called by:	Device drivers
Thread-safe:	No.
Available from ISR:	No.
Include:	<code>&lt;sys/alt_dev.h&gt;</code>
Description:	<p>The <code>alt_fs_reg()</code> function registers a file system with the HAL. After it is registered, a file system can be accessed using the standard I/O functions. Refer to the <i>Developing Programs Using the Hardware Abstraction Layer</i> chapter of the <i>Nios II Software Developer's Handbook</i>.</p> <p>System behavior is undefined in the event that a file system is registered with a name that conflicts with an existing device or file system.</p> <p><code>alt_fs_reg()</code> is not thread-safe if other threads are using the device list at the time that <code>alt_fs_reg()</code> is called. Call <code>alt_fs_reg()</code> only in the following circumstances:</p> <ul style="list-style-type: none"><li>■ When running in single-threaded mode.</li><li>■ From a device initialization function called by <code>alt_sys_init()</code>. <code>alt_sys_init()</code> should only be called by the single-threaded C startup code.</li></ul>
Return:	The return value is zero upon success. A negative return value indicates failure.
See also:	<code>alt_dev_reg()</code>

## alt\_get\_flash\_info()

Prototype:	<pre>int alt_get_flash_info(alt_flash_fd* fd,                       flash_region** info,                       int* number_of_regions)</pre>
Commonly called by:	C/C++ programs Device drivers
Thread-safe:	No.
Available from ISR:	No.
Include:	<code>&lt;sys/alt_flash.h&gt;</code>
Description:	<p>The <code>alt_get_flash_info()</code> function gets the details of the erase region of a flash part. The flash part is specified by the descriptor <code>fd</code>, a pointer to the start of the <code>flash_region</code> structures is returned in the <code>info</code> parameter, and the number of flash regions are returned in number of regions.</p> <p>Call this function only when operating in single-threaded mode.</p> <p>The only valid values for the <code>fd</code> parameter are those returned from the <code>alt_flash_open_dev</code> function. If any other value is passed, the behavior of this function is undefined.</p>
Return:	The return value is zero upon success. A negative return value indicates failure.
See also:	<pre>alt_erase_flash_block() alt_flash_close_dev() alt_flash_open_dev() alt_read_flash() alt_write_flash() alt_write_flash_block()</pre>

## alt\_ic\_irq\_disable()

Prototype:	<code>int alt_ic_irq_disable (alt_u32 ic_id, alt_u32 irq)</code>
Commonly called by:	C/C++ programs Device drivers
Thread-safe:	Yes.
Available from ISR:	No.
Include:	<code>&lt;sys/alt_irq.h&gt;</code>
Description:	<p>The <code>alt_ic_irq_disable()</code> function disables a single interrupt.</p> <p>The function arguments are as follows:</p> <ul style="list-style-type: none"> <li>■ <code>ic_id</code> is the interrupt controller identifier (ID) as defined in <b>system.h</b>, identifying the external interrupt controller in the daisy chain. This argument is ignored if the external interrupt controller interface is not implemented.</li> <li>■ <code>irq</code> is the IRQ number, as defined in <b>system.h</b>, identifying the interrupt to enable.</li> </ul> <p> A driver for an external interrupt controller (EIC) must implement this function.</p>
Return:	This function returns zero if successful, or nonzero otherwise. The function fails if the <code>irq</code> parameter is greater than the maximum interrupt port number supported by the external interrupt controller.
See also:	<pre> alt_irq_disable_all() alt_irq_enable() alt_irq_enable_all() alt_irq_enabled() alt_irq_register() alt_irq_disable() alt_ic_irq_enable() alt_ic_irq_enabled() alt_ic_isr_register() </pre>

## alt\_ic\_irq\_enable()

Prototype: `int alt_ic_irq_enable (alt_u32 ic_id, alt_u32 irq)`

Commonly called by: C/C++ programs

Device drivers

Thread-safe: Yes.

Available from ISR: No.

Include: `<sys/alt_irq.h>`

Description: The `alt_ic_irq_enable()` function enables a single interrupt.

The function arguments are as follows:

- `ic_id` is the interrupt controller ID as defined in **system.h**, identifying the external interrupt controller in the daisy chain. This argument is ignored if the external interrupt controller interface is not implemented.
- `irq` is the IRQ number, as defined in **system.h**, identifying the interrupt to enable.

 A driver for an external interrupt controller (EIC) must implement this function.

Return: This function returns zero if successful, or nonzero otherwise. The function fails if the `irq` parameter is greater than the maximum interrupt port number supported by the external interrupt controller.

See also:

```
alt_irq_disable()  
alt_irq_disable_all()  
alt_irq_enable_all()  
alt_irq_enabled()  
alt_irq_register()  
alt_irq_enable()  
alt_ic_irq_disable()  
alt_ic_irq_enabled()  
alt_ic_isr_register()
```

## alt\_ic\_irq\_enabled()

Prototype: `int alt_ic_irq_enabled (alt_u32 ic_id, alt_u32 irq)`

Commonly called by: Device drivers

Thread-safe: Yes.

Available from ISR: Yes.

Include: `<sys/alt_irq.h>`

Description: This function determines whether a specified interrupt is enabled.

The function arguments are as follows:

- `ic_id` is the interrupt controller ID as defined in **system.h**, identifying the external interrupt controller in the daisy chain. This argument is ignored if the external interrupt controller interface is not implemented.
- `irq` is the IRQ number, as defined in **system.h**, identifying the interrupt to enable.

 A driver for an external interrupt controller (EIC) must implement this function.

Return: Returns zero if the specified interrupt is disabled, and nonzero otherwise.

See also:

- `alt_irq_disable()`
- `alt_irq_disable_all()`
- `alt_irq_enable()`
- `alt_irq_enable_all()`
- `alt_irq_register()`
- `alt_irq_enabled()`
- `alt_ic_irq_disable()`
- `alt_ic_irq_enable()`
- `alt_ic_isr_register()`

## alt\_ic\_isr\_register()

Prototype:

```
int alt_ic_isr_register (alt_u32 ic_id,
                        alt_u32 irq,
                        alt_isr_func isr,
                        void*   isr_context,
                        void*   flags)
```

Commonly called by: Device drivers

Thread-safe: Yes.

Available from ISR: No.

Include: <sys/alt\_irq.h>

Description: The `alt_ic_isr_register()` function registers an ISR. If the function is successful, the requested interrupt is enabled on return, and `isr` and `isr_context` are inserted in the vector table.

The function arguments are as follows:

- `ic_id` is the interrupt controller ID as defined in **system.h**, identifying the external interrupt controller in the daisy chain. This argument is ignored if the external interrupt controller interface is not implemented.
- `irq` is the IRQ number, as defined in **system.h**, identifying the interrupt to register.
- `isr` is the function that is called when the interrupt is accepted.
- `isr_context` is the input argument to `isr`. `isr_context` points to a data structure associated with the device driver instance.
- `flags` is reserved.

The ISR function prototype is defined as follows:

```
typedef void (*alt_isr_func) (void* isr_context);
```

Calls to `alt_ic_isr_register()` replace previously registered handlers for interrupt `irq`.

If `isr` is set to null, the interrupt is disabled.

 A driver for an external interrupt controller (EIC) must implement this function.

Return: This function returns zero if successful, or nonzero otherwise. The function fails if the `irq` parameter is greater than the maximum interrupt port number supported by the external interrupt controller.

See also:

```
alt_irq_disable()
alt_irq_disable_all()
alt_irq_enable()
alt_irq_enable_all()
alt_irq_enabled()
alt_irq_register()
alt_ic_irq_disable()
alt_ic_irq_enable()
alt_ic_irq_enabled()
```

## alt\_icache\_flush()

Prototype:	<code>void alt_icache_flush (void* start, alt_u32 len)</code>
Commonly called by:	C/C++ programs Device drivers
Thread-safe:	Yes.
Available from ISR:	Yes.
Include:	<code>&lt;sys/alt_cache.h&gt;</code>
Description:	<p>The <code>alt_icache_flush()</code> function invalidates the instruction cache for a memory region of length <code>len</code> bytes, starting at address <code>start</code>.</p> <p>In processors without instruction caches, it has no effect.</p>
Return:	—
See also:	<code>alt_dcache_flush()</code> <code>alt_dcache_flush_all()</code> <code>alt_icache_flush_all()</code> <code>alt_remap_cached()</code> <code>alt_remap_uncached()</code> <code>alt_uncached_free()</code> <code>alt_uncached_malloc()</code>



## alt\_icache\_flush\_all()

Prototype:	<code>void alt_icache_flush_all (void)</code>
Commonly called by:	C/C++ programs Device drivers
Thread-safe:	Yes.
Available from ISR:	Yes.
Include:	<code>&lt;sys/alt_cache.h&gt;</code>
Description:	<p>The <code>alt_icache_flush_all()</code> function invalidates the entire contents of the instruction cache.</p> <p>In processors without instruction caches, it has no effect.</p>
Return:	—
See also:	<code>alt_dcache_flush()</code> <code>alt_dcache_flush_all()</code> <code>alt_icache_flush()</code> <code>alt_remap_cached()</code> <code>alt_remap_uncached()</code> <code>alt_uncached_free()</code> <code>alt_uncached_malloc()</code>

## alt\_instruction\_exception\_register()

Prototype:	<pre>void alt_instruction_exception_register (     alt_exception_result (*handler)     ( alt_exception_cause cause,       alt_u32             exception_pc,       alt_u32             bad_addr ))</pre>
Commonly called by:	C/C++ programs Device drivers
Thread-safe:	No.
Available from ISR:	Yes.
Include:	<sys/alt_exceptions.h>
Description:	<p>The HAL API function <code>alt_instruction_exception_register()</code> registers an instruction-related exception handler. The <code>handler</code> argument is a pointer to the instruction-related exception handler.</p> <p>You can only use this API function if you have enabled the <code>hal.enable_instruction_related_exceptions_api</code> setting in the board support package (BSP). For details, refer to “Settings” in the <i>Nios II Software Build Tools Reference</i> chapter of the <i>Nios II Software Developer's Handbook</i>.</p> <p>Register the instruction-related exception handler as early as possible in function <code>main()</code>. This allows you to handle abnormal conditions during startup.</p> <p>You can register an exception handler from the <code>alt_main()</code> function.</p> <p>A call to <code>alt_instruction_exception_register()</code> replaces the previously registered exception handler, if any. If <code>handler</code> is set to null, the instruction-related exception handler is removed.</p> <p>For further usage details, refer to the <i>Exception Handling</i> chapter of the <i>Nios II Software Developer's Handbook</i>.</p>
Return:	—
See also:	<pre>alt_irq_register() alt_exception_cause_generated_bad_addr()</pre>

## alt\_irq\_disable()

Prototype: `int alt_irq_disable (alt_u32 id)`

Commonly called by: C/C++ programs  
Device drivers


Thread-safe: Yes.

Available from ISR: No.

Include: `<sys/alt_irq.h>`

Description: The `alt_irq_disable()` function disables a single interrupt.

 This function is part of the legacy HAL interrupt API, which is deprecated. Altera recommends using the enhanced HAL interrupt API.

 For details about using the enhanced HAL interrupt API, refer to “Interrupt Service Routines” in the *Exception Handling* chapter of the *Nios II Software Developer's Handbook*.

Return: The return value is zero.

See also:

- `alt_irq_disable_all()`
- `alt_irq_enable()`
- `alt_irq_enable_all()`
- `alt_irq_enabled()`
- `alt_irq_register()`
- `alt_ic_irq_disable()`
- `alt_ic_irq_enable()`
- `alt_ic_irq_enabled()`
- `alt_ic_isr_register()`

## alt\_irq\_disable\_all()

Prototype:	<code>alt_irq_context alt_irq_disable_all (void)</code>
Commonly called by:	C/C++ programs Device drivers
Thread-safe:	Yes.
Available from ISR:	No.
Include:	<code>&lt;sys/alt_irq.h&gt;</code>
Description:	The <code>alt_irq_disable_all()</code> function disables all maskable interrupts. Nonmaskable interrupts (NMIs) are unaffected.
Return:	Pass the return value as the input argument to a subsequent call to <code>alt_irq_enable_all()</code> .
See also:	<code>alt_irq_disable()</code> <code>alt_irq_enable()</code> <code>alt_irq_enable_all()</code> <code>alt_irq_enabled()</code> <code>alt_irq_register()</code> <code>alt_ic_irq_disable()</code> <code>alt_ic_irq_enable()</code> <code>alt_ic_irq_enabled()</code> <code>alt_ic_isr_register()</code>

## alt\_irq\_enable()

Prototype: `int alt_irq_enable (alt_u32 id)`

Commonly called by: C/C++ programs

Device drivers


Thread-safe: Yes.

Available from ISR: No.

Include: `<sys/alt_irq.h>`

Description: The `alt_irq_enable()` function enables a single interrupt.

 This function is part of the legacy HAL interrupt API, which is deprecated. Altera recommends using the enhanced HAL interrupt API.

 For details about using the enhanced HAL interrupt API, refer to “Interrupt Service Routines” in the *Exception Handling* chapter of the *Nios II Software Developer's Handbook*.

Return: The return value is zero.

See also:

- `alt_irq_disable()`
- `alt_irq_disable_all()`
- `alt_irq_enable_all()`
- `alt_irq_enabled()`
- `alt_irq_register()`
- `alt_ic_irq_disable()`
- `alt_ic_irq_enable()`
- `alt_ic_irq_enabled()`
- `alt_ic_isr_register()`

## alt\_irq\_enable\_all()

Prototype:	<code>void alt_irq_enable_all (alt_irq_context context)</code>
Commonly called by:	C/C++ programs Device drivers
Thread-safe:	Yes.
Available from ISR:	Yes.
Include:	<code>&lt;sys/alt_irq.h&gt;</code>
Description:	The <code>alt_irq_enable_all()</code> function enables all interrupts that were previously disabled by <code>alt_irq_disable_all()</code> . The input argument, <code>context</code> , is the value returned by a previous call to <code>alt_irq_disable_all()</code> . Using <code>context</code> allows nested calls to <code>alt_irq_disable_all()</code> and <code>alt_irq_enable_all()</code> . As a result, <code>alt_irq_enable_all()</code> does not necessarily enable all interrupts, such as interrupts explicitly disabled by <code>alt_irq_disable()</code> .
Return:	—
See also:	<code>alt_irq_disable()</code> <code>alt_irq_disable_all()</code> <code>alt_irq_enable()</code> <code>alt_irq_enabled()</code> <code>alt_irq_register()</code> <code>alt_ic_irq_disable()</code> <code>alt_ic_irq_enable()</code> <code>alt_ic_irq_enabled()</code> <code>alt_ic_isr_register()</code>

## alt\_irq\_enabled()

Prototype: `int alt_irq_enabled (void)`

Commonly called by: Device drivers


Thread-safe: Yes.

Available from ISR: Yes.

Include: `<sys/alt_irq.h>`

Description: Determines whether maskable exceptions (`status.PIE`) are enabled.

 This function is part of the legacy HAL interrupt API, which is deprecated. Altera recommends using the enhanced HAL interrupt API.



 For details about using the enhanced HAL interrupt API, refer to “Interrupt Service Routines” in the *Exception Handling* chapter of the *Nios II Software Developer's Handbook*.

Return: Returns zero if interrupts are disabled, and non-zero otherwise.

See also:

- `alt_irq_disable()`
- `alt_irq_disable_all()`
- `alt_irq_enable()`
- `alt_irq_enable_all()`
- `alt_irq_register()`
- `alt_ic_irq_disable()`
- `alt_ic_irq_enable()`
- `alt_ic_irq_enabled()`
- `alt_ic_isr_register()`

## alt\_irq\_register()

Prototype:	<pre>int alt_irq_register (alt_u32 id,                       void*   context,                       void    (*isr)(void*, alt_u32))</pre>
Commonly called by:	Device drivers
Thread-safe:	Yes.
Available from ISR:	No.
Include:	<sys/alt_irq.h>
Description:	<p>The <code>alt_irq_register()</code> function registers an ISR. If the function is successful, the requested interrupt is enabled on return.</p> <p>The input argument <code>id</code> is the interrupt to enable. <code>isr</code> is the function that is called when the interrupt is active. <code>context</code> and <code>id</code> are the two input arguments to <code>isr</code>.</p> <p>Calls to <code>alt_irq_register()</code> replace previously registered handlers for interrupt <code>id</code>. If <code>irq_handler</code> is set to null, the interrupt is disabled.</p> <p> This function is part of the legacy HAL interrupt API, which is deprecated. Altera recommends using the enhanced HAL interrupt API.</p> <p> For details about using the enhanced HAL interrupt API, refer to “Interrupt Service Routines” in the <i>Exception Handling</i> chapter of the <i>Nios II Software Developer's Handbook</i>.</p>
Return:	The <code>alt_irq_register()</code> function returns zero if successful, or non-zero otherwise.
See also:	<pre>alt_irq_disable() alt_irq_disable_all() alt_irq_enable() alt_irq_enable_all() alt_irq_enabled() alt_ic_irq_disable() alt_ic_irq_enable() alt_ic_irq_enabled() alt_ic_isr_register()</pre>



## alt\_llist\_insert()

Prototype:	<pre>void alt_llist_insert(alt_llist* list,                     alt_llist* entry)</pre>
Commonly called by:	C/C++ programs Device drivers
Thread-safe:	No.
Available from ISR:	Yes.
Include:	<code>&lt;sys/alt_llist.h&gt;</code>
Description:	The <code>alt_llist_insert()</code> function inserts the doubly linked list entry <code>entry</code> in the list <code>list</code> . This operation is not reentrant. For example, if a list can be manipulated from different threads, or from within both application code and an ISR, some mechanism is required to protect access to the list. Interrupts can be locked, or in MicroC/OS-II, a <code>mutex</code> can be used.
Return:	—
See also:	<code>alt_llist_remove()</code>

## alt\_llist\_remove()

Prototype:	<code>void alt_llist_remove(alt_llist* entry)</code>
Commonly called by:	C/C++ programs Device drivers
Thread-safe:	No.
Available from ISR:	Yes.
Include:	<code>&lt;sys/alt_llist.h&gt;</code>
Description:	The <code>alt_llist_remove()</code> function removes the doubly linked list entry <code>entry</code> from the list it is currently a member of. This operation is not reentrant. For example if a list can be manipulated from different threads, or from within both application code and an ISR, some mechanism is required to protect access to the list. Interrupts can be locked, or in MicroC/OS-II, a <code>mutex</code> can be used.
Return:	—
See also:	<code>alt_llist_insert()</code>

## alt\_load\_section()

```

Prototype:      void alt_load_section(alt_u32* from,
                                     alt_u32* to,
                                     alt_u32* end)

```

Commonly called by: C/C++ programs

Thread-safe: No.

Available from ISR: No.

```
Include:      <sys/alt_load.h>
```

Description: When operating in run-from-flash mode, the sections `.exceptions`, `.rodata`, and `.rwdata` are automatically loaded from the boot device to RAM at boot time. However, if there are any additional sections that require loading, the `alt_load_section()` function loads them manually before these sections are used.

The input argument `from` is the start address in the boot device of the section; `to` is the start address in RAM of the section, and `end` is the end address in RAM of the section.

To load one of the additional memory sections provided by the default linker script, use the macro `ALT_LOAD_SECTION_BY_NAME` rather than calling `alt_load_section()` directly. For example, to load the section `.onchip_ram`, use the following code:

```
ALT_LOAD_SECTION_BY_NAME(onchip_ram);
```

The leading ‘.’ is omitted in the section name. This macro is defined in the header **sys/alt\_load.h**.

Return: —

See also: —

## alt\_nticks()

Prototype:	<code>alt_u32 alt_nticks (void)</code>
Commonly called by:	C/C++ programs Device drivers
Thread-safe:	Yes.
Available from ISR:	Yes.
Include:	<code>&lt;sys/alt_alarm.h&gt;</code>
Description:	The <code>alt_nticks()</code> function.
Return:	Returns the number of elapsed system clock tick since reset. It returns zero if there is no system clock available.
See also:	<code>alt_alarm_start()</code> <code>alt_alarm_stop()</code> <code>alt_sysclk_init()</code> <code>alt_tick()</code> <code>alt_ticks_per_second()</code> <code>gettimeofday()</code> <code>settimeofday()</code> <code>times()</code> <code>usleep()</code>

## alt\_read\_flash()

Prototype:	<pre>int alt_read_flash(alt_flash_fd* fd,                     int          offset,                     void*        dest_addr,                     int          length)</pre>
Commonly called by:	C/C++ programs Device drivers
Thread-safe:	No.
Available from ISR:	No.
Include:	<code>&lt;sys/alt_flash.h&gt;</code>
Description:	<p>The <code>alt_read_flash()</code> function reads data from flash. <code>length</code> bytes are read from the flash <code>fd</code>, starting <code>offset</code> bytes from the beginning of the flash and are written to the location <code>dest_addr</code>.</p> <p>Call this function only when operating in single-threaded mode.</p> <p>The only valid values for the <code>fd</code> parameter are those returned from the <code>alt_flash_open_dev</code> function. If any other value is passed, the behavior of this function is undefined.</p>
Return:	The return value is zero on success and nonzero otherwise.
See also:	<pre>alt_erase_flash_block() alt_flash_close_dev() alt_flash_open_dev() alt_get_flash_info() alt_write_flash() alt_write_flash_block()</pre>

## alt\_remap\_cached()

Prototype:	<pre>void* alt_remap_cached (volatile void* ptr,                         alt_u32      len);</pre>
Commonly called by:	C/C++ programs Device drivers
Thread-safe:	Yes.
Available from ISR:	No.
Include:	<code>&lt;sys/alt_cache.h&gt;</code>
Description:	<p>The <code>alt_remap_cached()</code> function remaps a region of memory for cached access. The memory to map is <code>len</code> bytes, starting at address <code>ptr</code>.</p> <p>Processors that do not have a data cache return uncached memory.</p>
Return:	The return value for this function is the remapped memory region.
See also:	<pre>alt_dcache_flush() alt_dcache_flush_all() alt_icache_flush() alt_icache_flush_all() alt_remap_uncached() alt_uncached_free() alt_uncached_malloc()</pre>

## alt\_remap\_uncached()

Prototype:	<pre>volatile void* alt_remap_uncached (void* ptr,                                 alt_u32 len);</pre>
Commonly called by:	C/C++ programs Device drivers
Thread-safe:	Yes.
Available from ISR:	No.
Include:	<code>&lt;sys/alt_cache.h&gt;</code>
Description:	<p>The <code>alt_remap_uncached()</code> function remaps a region of memory for uncached access. The memory to map is <code>len</code> bytes, starting at address <code>ptr</code>.</p> <p>Processors that do not have a data cache return uncached memory.</p>
Return:	The return value for this function is the remapped memory region.
See also:	<pre>alt_dcache_flush() alt_dcache_flush_all() alt_icache_flush() alt_icache_flush_all() alt_remap_cached() alt_uncached_free() alt_uncached_malloc()</pre>

## alt\_sysclk\_init()

Prototype:	<code>int alt_sysclk_init (alt_u32 nticks)</code>
Commonly called by:	Device drivers
Thread-safe:	No.
Available from ISR:	No.
Include:	<code>&lt;sys/alt_alarm.h&gt;</code>
Description:	<p>The <code>alt_sysclk_init()</code> function registers the presence of a system clock driver. The input argument is the number of ticks per second at which the system clock is run.</p> <p>The expectation is that this function is only called from within <code>alt_sys_init()</code>, that is, while the system is running in single-threaded mode. Concurrent calls to this function might lead to unpredictable results.</p>
Return:	This function returns zero on success; otherwise it returns a negative value. The call can fail if a system clock driver is already registered, or if no system clock device is available.
See also:	<code>alt_alarm_start()</code> <code>alt_alarm_stop()</code> <code>alt_nticks()</code> <code>alt_tick()</code> <code>alt_ticks_per_second()</code> <code>gettimeofday()</code> <code>settimeofday()</code> <code>times()</code> <code>usleep()</code>



## alt\_tick()

Prototype:	<code>void alt_tick (void)</code>
Commonly called by:	Device drivers
Thread-safe:	No.
Available from ISR:	Yes.
Include:	<code>&lt;sys/alt_alarm.h&gt;</code>
Description:	Only the system clock driver should call the <code>alt_tick()</code> function. The driver is responsible for making periodic calls to this function at the rate specified in the call to <code>alt_sysclk_init()</code> . This function provides notification to the system that a system clock tick has occurred. This function runs as a part of the ISR for the system clock driver.
Return:	—
See also:	<code>alt_alarm_start()</code> <code>alt_alarm_stop()</code> <code>alt_nticks()</code> <code>alt_sysclk_init()</code> <code>alt_ticks_per_second()</code> <code>gettimeofday()</code> <code>settimeofday()</code> <code>times()</code> <code>usleep()</code>

## alt\_ticks\_per\_second()

Prototype:	<code>alt_u32 alt_ticks_per_second (void)</code>
Commonly called by:	C/C++ programs Device drivers
Thread-safe:	Yes.
Available from ISR:	Yes.
Include:	<code>&lt;sys/alt_alarm.h&gt;</code>
Description:	The <code>alt_ticks_per_second()</code> function returns the number of system clock ticks that elapse per second. If there is no system clock available, the return value is zero.
Return:	Returns the number of system clock ticks that elapse per second.
See also:	<code>alt_alarm_start()</code> <code>alt_alarm_stop()</code> <code>alt_nticks()</code> <code>alt_sysclk_init()</code> <code>alt_tick()</code> <code>gettimeofday()</code> <code>settimeofday()</code> <code>times()</code> <code>usleep()</code>

## alt\_timestamp()

Prototype:	<code>alt_u32 alt_timestamp (void)</code>
Commonly called by:	C/C++ programs
Thread-safe:	See description.
Available from ISR:	See description.
Include:	<code>&lt;sys/alt_timestamp.h&gt;</code>
Description:	<p>The <code>alt_timestamp()</code> function returns the current value of the timestamp counter. Refer to “Using Timer Devices” in the <i>Developing Programs Using the Hardware Abstraction Layer</i> chapter of the <i>Nios II Software Developer’s Handbook</i>. The implementation of this function is provided by the timestamp driver. Therefore, whether this function is thread-safe and or available at interrupt level depends on the underlying driver.</p> <p>Always call the <code>alt_timestamp_start()</code> function before any calls to <code>alt_timestamp()</code>. Otherwise the behavior of <code>alt_timestamp()</code> is undefined.</p>
Return:	Returns the current value of the timestamp counter.
See also:	<code>alt_timestamp_freq()</code> <code>alt_timestamp_start()</code>

## alt\_timestamp\_freq()

Prototype:	<code>alt_u32 alt_timestamp_freq (void)</code>
Commonly called by:	C/C++ programs
Thread-safe:	See description.
Available from ISR:	See description.
Include:	<code>&lt;sys/alt_timestamp.h&gt;</code>
Description:	The <code>alt_timestamp_freq()</code> function returns the rate at which the timestamp counter increments. Refer to “Using Timer Devices” in the <i>Developing Programs Using the Hardware Abstraction Layer</i> chapter of the <i>Nios II Software Developer's Handbook</i> . The implementation of this function is provided by the timestamp driver. Therefore, whether this function is thread-safe and or available at interrupt level depends on the underlying driver.
Return:	The returned value is the number of counter ticks per second.
See also:	<code>alt_timestamp()</code> <code>alt_timestamp_start()</code>

## alt\_timestamp\_start()

Prototype:	<code>int alt_timestamp_start (void)</code>
Commonly called by:	C/C++ programs
Thread-safe:	See description.
Available from ISR:	See description.
Include:	<code>&lt;sys/alt_timestamp.h&gt;</code>
Description:	<p>The <code>alt_timestamp_start()</code> function starts the system timestamp counter. Refer to “Using Timer Devices” in the <i>Developing Programs Using the Hardware Abstraction Layer</i> chapter of the <i>Nios II Software Developer’s Handbook</i>. The implementation of this function is provided by the timestamp driver. Therefore, whether this function is thread-safe and or available at interrupt level depends on the underlying driver.</p> <p>This function resets the counter to zero, and starts the counter running.</p>
Return:	The return value is zero on success and nonzero otherwise.
See also:	<code>alt_timestamp()</code> <code>alt_timestamp_freq()</code>

## alt\_uncached\_free()

Prototype:	<code>void alt_uncached_free (volatile void* ptr)</code>
Commonly called by:	C/C++ programs Device drivers
Thread-safe:	Yes.
Available from ISR:	No.
Include:	<code>&lt;sys/alt_cache.h&gt;</code>
Description:	The <code>alt_uncached_free()</code> function causes the memory pointed to by <code>ptr</code> to be de-allocated, that is, made available for future allocation through a call to <code>alt_uncached_malloc()</code> . The input pointer, <code>ptr</code> , points to a region of memory previously allocated through a call to <code>alt_uncached_malloc()</code> . Behavior is undefined if this is not the case.
Return:	—
See also:	<code>alt_dcache_flush()</code> <code>alt_dcache_flush_all()</code> <code>alt_icache_flush()</code> <code>alt_icache_flush_all()</code> <code>alt_remap_cached()</code> <code>alt_remap_uncached()</code> <code>alt_uncached_malloc()</code>

## alt\_uncached\_malloc()

Prototype:	<code>volatile void* alt_uncached_malloc (size_t size)</code>
Commonly called by:	C/C++ programs Device drivers
Thread-safe:	Yes.
Available from ISR:	No.
Include:	<code>&lt;sys/alt_cache.h&gt;</code>
Description:	<p>The <code>alt_uncached_malloc()</code> function allocates a region of uncached memory of length <code>size</code> bytes. Regions of memory allocated in this way can be released using the <code>alt_uncached_free()</code> function.</p> <p>Processors that do not have a data cache return uncached memory.</p>
Return:	If sufficient memory cannot be allocated, this function returns null, otherwise a pointer to the allocated space is returned.
See also:	<code>alt_dcache_flush()</code> <code>alt_dcache_flush_all()</code> <code>alt_icache_flush()</code> <code>alt_icache_flush_all()</code> <code>alt_remap_cached()</code> <code>alt_remap_uncached()</code> <code>alt_uncached_free()</code>

## alt\_write\_flash()

Prototype:

```
int alt_write_flash(alt_flash_fd* fd,
                    int           offset,
                    const void*   src_addr,
                    int           length)
```

Commonly called by: C/C++ programs

Device drivers

Thread-safe: No.

Available from ISR: No.

Include: `<sys/alt_flash.h>`

Description: The `alt_write_flash()` function writes data to flash. The data to be written is at address `src_addr`. `length` bytes are written to the flash `fd`, `offset` bytes from the beginning of the flash device address space.

Call this function only when operating in single-threaded mode. This function does not preserve any unwritten areas of any flash sectors affected by this write. Refer to “Using Flash Devices” in the *Developing Programs Using the Hardware Abstraction Layer* chapter of the *Nios II Software Developer's Handbook*.

The only valid values for the `fd` parameter are those returned from the `alt_flash_open_dev` function. If any other value is passed, the behavior of this function is undefined.


Return: The return value is zero on success and nonzero otherwise.

See also:

```
alt_erase_flash_block()
alt_flash_close_dev()
alt_flash_open_dev()
alt_get_flash_info()
alt_read_flash()
alt_write_flash_block()
```



## alt\_write\_flash\_block()

Prototype:	<pre>int alt_write_flash_block(alt_flash_fd* fd,                           int          block_offset,                           int          data_offset,                           const void  *data,                           int          length)</pre>
Commonly called by:	C/C++ programs Device drivers
Thread-safe:	No.
Available from ISR:	No.
Include:	<sys/alt_flash.h>
Description:	<p>The <code>alt_write_flash_block()</code> function writes one block of data of flash. The data to be written is at address <code>data.length</code> bytes are written to the flash <code>fd</code>, into the block starting at offset <code>block_offset</code> from the beginning of the flash address space. The data starts at offset <code>data_offset</code> from the beginning of the flash address space.</p> <p> No check is performed on any of the parameters. Refer to “Using Flash Devices” in the <i>Developing Programs Using the Hardware Abstraction Layer</i> chapter of the <i>Nios II Software Developer's Handbook</i>.</p> <p>Call this function only when operating in single-threaded mode.</p> <p>The only valid values for the <code>fd</code> parameter are those returned from the <code>alt_flash_open_dev</code> function. If any other value is passed, the behavior of this function is undefined.</p>
Return:	The return value is zero on success and nonzero otherwise.
See also:	<pre>alt_erase_flash_block() alt_flash_close_dev() alt_flash_open_dev() alt_get_flash_info() alt_read_flash() alt_write_flash()</pre>

## close()

Prototype:	<code>int close (int fd)</code>
Commonly called by:	C/C++ programs Newlib C library
Thread-safe:	See description.
Available from ISR:	No.
Include:	<code>&lt;unistd.h&gt;</code>
Description:	<p>The <code>close()</code> function is the standard UNIX-style <code>close()</code> function, which closes the file descriptor <code>fd</code>.</p> <p>Calls to <code>close()</code> are thread-safe only if the implementation of <code>close()</code> provided by the driver that is manipulated is thread-safe.</p> <p>Valid values for the <code>fd</code> parameter are: <code>stdout</code>, <code>stdin</code>, and <code>stderr</code>, or any value returned from a call to <code>open()</code>.</p>
Return:	The return value is zero on success, and <code>-1</code> otherwise. If an error occurs, <code>errno</code> is set to indicate the cause.
See also:	<code>fcntl()</code> <code>fstat()</code> <code>ioctl()</code> <code>isatty()</code> <code>lseek()</code> <code>open()</code> <code>read()</code> <code>stat()</code> <code>write()</code> Newlib documentation

## **execve()**

Prototype:	<pre>int execve(const char *path,             char *const argv[],             char *const envp[])</pre>
Commonly called by:	Newlib C library
Thread-safe:	Yes.
Available from ISR:	Yes.
Include:	<code>&lt;unistd.h&gt;</code>
Description:	The <code>execve()</code> function is only provided for compatibility with newlib.
Return:	Calls to <code>execve()</code> always fail with the return code <code>-1</code> and <code>errno</code> set to <code>ENOSYS</code> .
See also:	Newlib documentation

## fcntl()

Prototype: `int fcntl(int fd, int cmd)`

Commonly called by: C/C++ programs

Thread-safe: No.

Available from ISR: No.

Include: `<unistd.h>`  
`<fcntl.h>`

Description: The `fcntl()` function is a limited implementation of the standard `fcntl()` system call, which can change the state of the flags associated with an open file descriptor. Normally these flags are set during the call to `open()`. The main use of this function is to change the state of a device from blocking to nonblocking (for device drivers that support this feature).

The input argument `fd` is the file descriptor to be manipulated. `cmd` is the command to execute, which can be either `F_GETFL` (return the current value of the flags) or `F_SETFL` (set the value of the flags).

Return: If `cmd` is `F_SETFL`, the argument `arg` is the new value of flags, otherwise `arg` is ignored. Only the flags `O_APPEND` and `O_NONBLOCK` can be updated by a call to `fcntl()`. All other flags remain unchanged. The return value is zero on success, or `-1` otherwise.

If `cmd` is `F_GETFL`, the return value is the current value of the flags. If an error occurs, `-1` is returned.

In the event of an error, `errno` is set to indicate the cause.

See also:

`close()`

`fstat()`

`ioctl()`

`isatty()`

`lseek()`

`read()`

`stat()`

`write()`

Newlib documentation

## fork()

Prototype:	<code>pid_t fork (void)</code>
Commonly called by:	Newlib C library
Thread-safe:	Yes.
Available from ISR:	no
Include:	<code>&lt;unistd.h&gt;</code>
Description:	The <code>fork( )</code> function is only provided for compatibility with newlib.
Return:	Calls to <code>fork( )</code> always fails with the return code <code>-1</code> and <code>errno</code> set to <code>ENOSYS</code> .
See also:	Newlib documentation

## fstat()

Prototype:	<code>int fstat (int fd, struct stat *st)</code>
Commonly called by:	C/C++ programs Newlib C library
Thread-safe:	See description.
Available from ISR:	No.
Include:	<code>&lt;sys/stat.h&gt;</code>
Description:	<p>The <code>fstat()</code> function obtains information about the capabilities of an open file descriptor. The underlying device driver fills in the input <code>st</code> structure with a description of its functionality. Refer to the header file <b>sys/stat.h</b> provided with the compiler for the available options.</p> <p>By default, file descriptors are marked as character devices, unless the underlying driver provides its own implementation of the <code>fstat()</code> function.</p> <p>Calls to <code>fstat()</code> are thread-safe only if the implementation of <code>fstat()</code> provided by the driver that is manipulated is thread-safe.</p> <p>Valid values for the <code>fd</code> parameter are: <code>stdout</code>, <code>stdin</code>, and <code>stderr</code>, or any value returned from a call to <code>open()</code>.</p>
Return:	The return value is zero on success, or <code>-1</code> otherwise. If the call fails, <code>errno</code> is set to indicate the cause of the error.
See also:	<code>close()</code> <code>fcntl()</code> <code>ioctl()</code> <code>isatty()</code> <code>lseek()</code> <code>open()</code> <code>read()</code> <code>stat()</code> <code>write()</code> Newlib documentation

## getpid()

Prototype:	<code>pid_t getpid (void)</code>
Commonly called by:	Newlib C library
Thread-safe:	Yes.
Available from ISR:	No.
Include:	<code>&lt;unistd.h&gt;</code>
Description:	The <code>getpid()</code> function is provided for newlib compatibility and obtains the current process <code>id</code> .
Return:	Because HAL systems cannot contain multiple processes, <code>getpid()</code> always returns the same <code>id</code> number.
See also:	Newlib documentation

## gettimeofday()

Prototype:	<pre>int gettimeofday(struct timeval *ptimeval,                  struct timezone *ptimezone)</pre>
Commonly called by:	C/C++ programs Newlib C library
Thread-safe:	See description.
Available from ISR:	Yes.
Include:	<code>&lt;sys/time.h&gt;</code>
Description:	<p>The <code>gettimeofday()</code> function obtains a time structure that indicates the current time. This time is calculated using the elapsed number of system clock ticks, and the current time value set by the most recent call to <code>settimeofday()</code>.</p> <p>If this function is called concurrently with a call to <code>settimeofday()</code>, the value returned by <code>gettimeofday()</code> is unreliable; however, concurrent calls to <code>gettimeofday()</code> are legal.</p>
Return:	The return value is zero on success. If no system clock is available, the return value is <code>-ENOTSUP</code> .
See also:	<pre>alt_alarm_start() alt_alarm_stop() alt_nticks() alt_sysclk_init() alt_tick() alt_ticks_per_second() settimeofday() times() usleep() Newlib documentation</pre>



## ioctl()

Prototype:	<code>int ioctl (int fd, int req, void* arg)</code>
Commonly called by:	C/C++ programs
Thread-safe:	See description.
Available from ISR:	No.
Include:	<code>&lt;sys/ioctl.h&gt;</code>
Description:	<p>The <code>ioctl()</code> function allows application code to manipulate the I/O capabilities of a device driver in driver-specific ways. This function is equivalent to the standard UNIX <code>ioctl()</code> function. The input argument <code>fd</code> is an open file descriptor for the device to manipulate, <code>req</code> is an enumeration defining the operation request, and the interpretation of <code>arg</code> is request specific.</p> <p>For file subsystems, <code>ioctl()</code> is wrapper function that passes control directly to the appropriate device driver's <code>ioctl()</code> function (as registered in the driver's <code>alt_dev</code> structure).</p> <p>For devices, <code>ioctl()</code> handles <code>TIOCEXCL</code> and <code>TIOCNXCL</code> requests internally, without calling the device driver. These requests lock and release a device for exclusive access. For requests other than <code>TIOCEXCL</code> and <code>TIOCNXCL</code>, <code>ioctl()</code> passes control to the device driver's <code>ioctl()</code> function.</p> <p>Calls to <code>ioctl()</code> are thread-safe only if the implementation of <code>ioctl()</code> provided by the driver that is manipulated is thread-safe.</p> <p>Valid values for the <code>fd</code> parameter are: <code>stdout</code>, <code>stdin</code>, and <code>stderr</code>, or any value returned from a call to <code>open()</code>.</p>
Return:	The interpretation of the return value is request specific. If the call fails, <code>errno</code> is set to indicate the cause of the error.
See also:	<p><code>close()</code></p> <p><code>fcntl()</code></p> <p><code>fstat()</code></p> <p><code>isatty()</code></p> <p><code>lseek()</code></p> <p><code>open()</code></p> <p><code>read()</code></p> <p><code>stat()</code></p> <p><code>write()</code></p> <p>Newlib documentation</p>

## isatty()

Prototype:	<code>int isatty(int fd)</code>
Commonly called by:	C/C++ programs Newlib C library
Thread-safe:	See description.
Available from ISR:	No.
Include:	<code>&lt;unistd.h&gt;</code>
Description:	<p>The <code>isatty()</code> function determines whether the device associated with the open file descriptor <code>fd</code> is a terminal device. This implementation uses the driver's <code>fstat()</code> function to determine its reply.</p> <p>Calls to <code>isatty()</code> are thread-safe only if the implementation of <code>fstat()</code> provided by the driver that is manipulated is thread-safe.</p>
Return:	The return value is 1 if the device is a character device, and zero otherwise. If an error occurs, <code>errno</code> is set to indicate the cause.
See also:	<code>close()</code> <code>fcntl()</code> <code>fstat()</code> <code>ioctl()</code> <code>lseek()</code> <code>open()</code> <code>read()</code> <code>stat()</code> <code>write()</code> Newlib documentation

## kill()

Prototype:	<code>int kill(int pid, int sig)</code>
Commonly called by:	Newlib C library
Thread-safe:	Yes.
Available from ISR:	Yes.
Include:	<code>&lt;signal.h&gt;</code>
Description:	<p>The <code>kill()</code> function is used by newlib to send signals to processes. The input argument <code>pid</code> is the <code>id</code> of the process to signal, and <code>sig</code> is the signal to send. As there is only a single process in the HAL, the only valid values for <code>pid</code> are either the current process <code>id</code>, as returned by <code>getpid()</code>, or the broadcast values, that is, <code>pid</code> must be less than or equal to zero.</p> <p>The following signals result in an immediate shutdown of the system, without call to <code>exit()</code>: <code>SIGABRT</code>, <code>SIGALRM</code>, <code>SIGFPE</code>, <code>SIGILL</code>, <code>SIGKILL</code>, <code>SIGPIPE</code>, <code>SIGQUIT</code>, <code>SIGSEGV</code>, <code>SIGTERM</code>, <code>SIGUSR1</code>, <code>SIGUSR2</code>, <code>SIGBUS</code>, <code>SIGPOLL</code>, <code>SIGPROF</code>, <code>SIGSYS</code>, <code>SIGTRAP</code>, <code>SIGVTALRM</code>, <code>SIGXCPU</code>, and <code>SIGXFSZ</code>.</p> <p>The following signals are ignored: <code>SIGCHLD</code> and <code>SIGURG</code>.</p> <p>All the remaining signals are treated as errors.</p>
Return:	The return value is zero on success, or <code>-1</code> otherwise. If the call fails, <code>errno</code> is set to indicate the cause of the error.
See also:	Newlib documentation


## link()

Prototype:	<pre>int link(const char *_path1,          const char *_path2)</pre>
Commonly called by:	Newlib C library
Thread-safe:	Yes.
Available from ISR:	Yes.
Include:	<unistd.h>
Description:	The <code>link()</code> function is only provided for compatibility with newlib.
Return:	Calls to <code>link()</code> always fails with the return code <code>-1</code> and <code>errno</code> set to <code>ENOSYS</code> .
See also:	Newlib documentation

## lseek()

Prototype:	<code>off_t lseek(int fd, off_t ptr, int whence)</code>
Commonly called by:	C/C++ programs Newlib C library
Thread-safe:	See description.
Available from ISR:	No.
Include:	<code>&lt;unistd.h&gt;</code>
Description:	<p>The <code>lseek()</code> function moves the read/write pointer associated with the file descriptor <code>fd</code>. <code>lseek()</code> is wrapper function that passes control directly to the <code>lseek()</code> function registered for the driver associated with the file descriptor. If the driver does not provide an implementation of <code>lseek()</code>, an error is reported.</p> <p><code>lseek()</code> corresponds to the standard UNIX <code>lseek()</code> function.</p> <p>You can use the following values for the input parameter, <code>whence</code>:</p> <ul style="list-style-type: none"><li>■ <code>SEEK_SET</code>—The offset is set to <code>ptr</code> bytes.</li><li>■ <code>SEEK_CUR</code>—The offset is incremented by <code>ptr</code> bytes.</li><li>■ <code>SEEK_END</code>—The offset is set to the end of the file plus <code>ptr</code> bytes.</li></ul> <p>Calls to <code>lseek()</code> are thread-safe only if the implementation of <code>lseek()</code> provided by the driver that is manipulated is thread-safe.</p> <p>Valid values for the <code>fd</code> parameter are: <code>stdout</code>, <code>stdin</code>, and <code>stderr</code>, or any value returned from a call to <code>open()</code>.</p>
Return:	On success, the return value is a nonnegative file pointer. The return value is <code>-1</code> in the event of an error. If the call fails, <code>errno</code> is set to indicate the cause of the error.
See also:	<code>close()</code> <code>fcntl()</code> <code>fstat()</code> <code>ioctl()</code> <code>isatty()</code> <code>open()</code> <code>read()</code> <code>stat()</code> <code>write()</code> Newlib documentation

## open()

Prototype:	<code>int open (const char* pathname, int flags, mode_t mode)</code>
Commonly called by:	C/C++ programs
Thread-safe:	See description.
Available from ISR:	No.
Include:	<code>&lt;unistd.h&gt;</code> <code>&lt;fcntl.h&gt;</code>
Description:	<p>The <code>open()</code> function opens a file or device and returns a file descriptor (a small, nonnegative integer for use in read, write, etc.)</p> <p><code>flags</code> is one of: <code>O_RDONLY</code>, <code>O_WRONLY</code>, or <code>O_RDWR</code>, which request opening the file in read-only, write-only, or read/write mode, respectively.</p> <p>You can also bitwise-OR <code>flags</code> with <code>O_NONBLOCK</code>, which causes the file to be opened in nonblocking mode. Neither <code>open()</code> nor any subsequent operation on the returned file descriptor causes the calling process to wait.</p> <p> Not all file systems/devices recognize this option.</p> <p><code>mode</code> specifies the permissions to use, if a new file is created. It is unused by current file systems, but is maintained for compatibility.</p> <p>Calls to <code>open()</code> are thread-safe only if the implementation of <code>open()</code> provided by the driver that is manipulated is thread-safe.</p>
Return:	The return value is the new file descriptor, and <code>-1</code> otherwise. If an error occurs, <code>errno</code> is set to indicate the cause.
See also:	<p><code>close()</code></p> <p><code>fcntl()</code></p> <p><code>fstat()</code></p> <p><code>ioctl()</code></p> <p><code>isatty()</code></p> <p><code>lseek()</code></p> <p><code>read()</code></p> <p><code>stat()</code></p> <p><code>write()</code></p> <p>Newlib documentation</p>

## read()

Prototype:	<code>int read(int fd, void *ptr, size_t len)</code>
Commonly called by:	C/C++ programs Newlib C library
Thread-safe:	See description.
Available from ISR:	No.
Include:	<code>&lt;unistd.h&gt;</code>
Description:	<p>The <code>read()</code> function reads a block of data from a file or device. <code>read()</code> is wrapper function that passes control directly to the <code>read()</code> function registered for the device driver associated with the open file descriptor <code>fd</code>. The input argument, <code>ptr</code>, is the location to place the data read and <code>len</code> is the length of the data to read in bytes.</p> <p>Calls to <code>read()</code> are thread-safe only if the implementation of <code>read()</code> provided by the driver that is manipulated is thread-safe.</p> <p>Valid values for the <code>fd</code> parameter are: <code>stdout</code>, <code>stdin</code>, and <code>stderr</code>, or any value returned from a call to <code>open()</code>.</p>
Return:	<p>The return argument is the number of bytes read, which might be less than the requested length</p> <p>The return value is <code>-1</code> upon an error. In the event of an error, <code>errno</code> is set to indicate the cause.</p>
See also:	<code>close()</code> <code>fcntl()</code> <code>fstat()</code> <code>ioctl()</code> <code>isatty()</code> <code>lseek()</code> <code>open()</code> <code>stat()</code> <code>write()</code> Newlib documentation

## sbrk()

Prototype:	<code>caddr_t sbrk(int incr)</code>
Commonly called by:	Newlib C library
Thread-safe:	No.
Available from ISR:	No.
Include:	<code>&lt;unistd.h&gt;</code>
Description:	The <code>sbrk()</code> function dynamically extends the data segment for the application. The input argument <code>incr</code> is the size of the block to allocate. Do not call <code>sbrk()</code> directly. If you wish to dynamically allocate memory, use the newlib <code>malloc()</code> function.
Return:	—
See also:	Newlib documentation



## settimeofday()

Prototype:	<pre>int settimeofday (const struct timeval *t,                   const struct timezone *tz)</pre>
Commonly called by:	C/C++ programs
Thread-safe:	No.
Available from ISR:	Yes.
Include:	<code>&lt;sys/time.h&gt;</code>
Description:	If the <code>settimeofday()</code> function is called concurrently with a call to <code>gettimeofday()</code> , the value returned by <code>gettimeofday()</code> is unreliable.
Return:	The return value is zero on success. If no system clock is available, the return value is -1, and <code>errno</code> is set to <code>ENOSYS</code> .
See also:	<pre>alt_alarm_start() alt_alarm_stop() alt_nticks() alt_sysclk_init() alt_tick() alt_ticks_per_second() gettimeofday() times() usleep()</pre>

## stat()

Prototype:	<pre>int stat(const char *file_name,         struct stat *buf);</pre>
Commonly called by:	C/C++ programs Newlib C library
Thread-safe:	See description.
Available from ISR:	No.
Include:	<code>&lt;sys/stat.h&gt;</code>
Description:	<p>The <code>stat()</code> function is similar to the <code>fstat()</code> function—It obtains status information about a file. Instead of using an open file descriptor, like <code>fstat()</code>, <code>stat()</code> takes the name of a file as an input argument.</p> <p>Calls to <code>stat()</code> are thread-safe only if the implementation of <code>stat()</code> provided by the driver that is manipulated is thread-safe.</p> <p>Internally, the <code>stat()</code> function is implemented as a call to <code>fstat()</code>. Refer to “<a href="#">fstat()</a>” on <a href="#">page 14-62</a>.</p>
Return:	—
See also:	<code>close()</code> <code>fcntl()</code> <code>fstat()</code> <code>ioctl()</code> <code>isatty()</code> <code>lseek()</code> <code>open()</code> <code>read()</code> <code>write()</code> Newlib documentation

## times()

Prototype:	<code>clock_t times (struct tms *buf)</code>
Commonly called by:	C/C++ programs Newlib C library
Thread-safe:	Yes.
Available from ISR:	Yes.
Include:	<code>&lt;sys/times.h&gt;</code>
Description:	<p>This <code>times()</code> function is provided for compatibility with newlib. It returns the number of clock ticks since reset. It also fills in the structure pointed to by the input parameter <code>buf</code> with time accounting information. The definition of the <code>tms</code> structure is:</p> <pre>typedef struct {     clock_t tms_utime;     clock_t tms_stime;     clock_t tms_cutime;     clock_t tms_cstime; };</pre> <p>The structure has the following elements:</p> <ul style="list-style-type: none"> <li>■ <code>tms_utime</code>: the processor time charged for the execution of user instructions</li> <li>■ <code>tms_stime</code>: the processor time charged for execution by the system on behalf of the process</li> <li>■ <code>tms_cutime</code>: the sum of the values of <code>tms_utime</code> and <code>tms_cutime</code> for all child processes</li> <li>■ <code>tms_cstime</code>: the sum of the values of <code>tms_stime</code> and <code>tms_cstime</code> for all child processes</li> </ul> <p>In practice, all elapsed time is accounted as system time. No time is ever attributed as user time. In addition, no time is allocated to child processes, as child processes cannot be spawned by the HAL.</p>
Return:	If there is no system clock available, the return value is zero, and <code>errno</code> is set to <code>ENOSYS</code> .
See also:	<pre>alt_alarm_start() alt_alarm_stop() alt_nticks() alt_sysclk_init() alt_tick() alt_ticks_per_second() gettimeofday() settimeofday() usleep()</pre> <p>Newlib documentation</p>

## unlink()

Prototype:	<code>int unlink(char *name)</code>
Commonly called by:	Newlib C library
Thread-safe:	Yes.
Available from ISR:	Yes.
Include:	<code>&lt;unistd.h&gt;</code>
Description:	The <code>unlink()</code> function is only provided for compatibility with newlib.
Return:	Calls to <code>unlink()</code> always fails with the return code <code>-1</code> and <code>errno</code> set to <code>ENOSYS</code> .
See also:	Newlib documentation

## usleep()

Prototype:	<code>int usleep (unsigned int us)</code>
Commonly called by:	C/C++ programs Device drivers
Thread-safe:	Yes.
Available from ISR:	No.
Include:	<code>&lt;unistd.h&gt;</code>
Description:	The <code>usleep()</code> function blocks until at least <code>us</code> microseconds have elapsed.
Return:	The <code>usleep()</code> function returns zero on success, or <code>-1</code> otherwise. If an error occurs, <code>errno</code> is set to indicate the cause. The current implementation always succeeds.
See also:	<code>alt_alarm_start()</code> <code>alt_alarm_stop()</code> <code>alt_nticks()</code> <code>alt_sysclk_init()</code> <code>alt_tick()</code> <code>alt_ticks_per_second()</code> <code>gettimeofday()</code> <code>settimeofday()</code> <code>times()</code>

## wait()

Prototype:	<code>int wait(int *status)</code>
Commonly called by:	Newlib C library
Thread-safe:	Yes.
Available from ISR:	Yes.
Include:	<code>&lt;sys/wait.h&gt;</code>
Description:	Newlib uses the <code>wait()</code> function to wait for all child processes to exit. Because the HAL does not support spawning child processes, this function returns immediately.
Return:	On return, the content of <code>status</code> is set to zero, which indicates there is no child processes. The return value is always <code>-1</code> and <code>errno</code> is set to <code>ECHILD</code> , which indicates that there are no child processes to wait for.
See also:	Newlib documentation

## write()

Prototype:	<code>int write(int fd, const void *ptr, size_t len)</code>
Commonly called by:	C/C++ programs Newlib C library
Thread-safe:	See description.
Available from ISR:	no
Include:	<code>&lt;unistd.h&gt;</code>
Description:	<p>The <code>write()</code> function writes a block of data to a file or device. <code>write()</code> is wrapper function that passes control directly to the <code>write()</code> function registered for the device driver associated with the file descriptor <code>fd</code>. The input argument <code>ptr</code> is the data to write and <code>len</code> is the length of the data in bytes.</p> <p>Calls to <code>write()</code> are thread-safe only if the implementation of <code>write()</code> provided by the driver that is manipulated is thread-safe.</p> <p>Valid values for the <code>fd</code> parameter are: <code>stdout</code>, <code>stdin</code>, and <code>stderr</code>, or any value returned from a call to <code>open()</code>.</p>
Return:	<p>The return argument is the number of bytes written, which might be less than the requested length.</p> <p>The return value is <code>-1</code> upon an error. In the event of an error, <code>errno</code> is set to indicate the cause.</p>
See also:	<p><code>close()</code> <code>fcntl()</code> <code>fstat()</code> <code>ioctl()</code> <code>isatty()</code> <code>lseek()</code> <code>open()</code> <code>read()</code> <code>stat()</code> Newlib documentation</p>

## Standard Types

In the interest of portability, the HAL uses a set of standard type definitions in place of the ANSI C built-in types. [Table 14–2](#) describes these types, which are defined in the header file `alt_types.h`.

**Table 14–2.** Standard Types

Type	Description
<code>alt_8</code>	Signed 8-bit integer.
<code>alt_u8</code>	Unsigned 8-bit integer.
<code>alt_16</code>	Signed 16-bit integer.
<code>alt_u16</code>	Unsigned 16-bit integer.
<code>alt_32</code>	Signed 32-bit integer.
<code>alt_u32</code>	Unsigned 32-bit integer.
<code>alt_64</code>	Signed 64-bit integer.
<code>alt_u64</code>	Unsigned 64-bit integer.

## Referenced Documents

This chapter references the following documents:

- *Developing Programs Using the Hardware Abstraction Layer* chapter of the *Nios II Software Developer's Handbook*
- *Exception Handling* chapter of the *Nios II Software Developer's Handbook*
- *Nios II Software Build Tools Reference* chapter of the *Nios II Software Developer's Handbook*
- *DMA Controller Core* chapter in *Volume 5: Embedded Peripherals* of the *Quartus II Handbook*.
- *Newlib ANSI C standard library documentation* installed with the Nios II EDS. On the Windows Start menu, click **Programs > Altera > Nios II <version> > Nios II Documentation**.

## Document Revision History

[Table 14–3](#) shows the revision history for this document.



**Table 14-3.** Document Revision History

Date & Document Version	Changes Made	Summary of Changes
November 2009 v9.1.0	<ul style="list-style-type: none"> <li>Document new API functions: <code>alt_ic_irq_disable()</code>, <code>alt_ic_irq_enable()</code>, <code>alt_ic_irq_enabled()</code>, and <code>alt_ic_isr_register()</code></li> <li>Deprecate API functions <code>alt_irq_disable()</code>, <code>alt_irq_enable()</code>, <code>alt_irq_enabled()</code>, and <code>alt_irq_register()</code></li> </ul>	<ul style="list-style-type: none"> <li>Introduce enhanced HAL interrupt API</li> <li>Deprecate legacy HAL interrupt API</li> </ul>
March 2009 v9.0.0	<ul style="list-style-type: none"> <li>Corrected minor typographical errors.</li> </ul>	
May 2008 v8.0.0	Added <code>alt_instruction_exception_register()</code> and <code>alt_exception_cause_generated_bad_addr()</code> for instruction-related exception handlers.	<ul style="list-style-type: none"> <li>Advanced exceptions added to Nios II core</li> <li>Instruction-related exception handling added to HAL</li> </ul>
October 2007 v7.2.0	No change from previous release.	
May 2007 v7.1.0	<ul style="list-style-type: none"> <li>Added table of contents to “Introduction” section.</li> <li>Added Referenced Documents section.</li> </ul>	
March 2007 v7.0.0	No change from previous release.	
November 2006 v6.1.0	Function <code>open()</code> requires <code>fcntl.h</code> .	
May 2006 v6.0.0	No change from previous release.	
October 2005 v5.1.0	Added API entries for “ <code>alt_irq_disable()</code> ” and “ <code>alt_irq_enable()</code> ”, which were previously omitted by error.	
May 2005 v5.0.0	<ul style="list-style-type: none"> <li>Added <code>alt_load_section()</code> function</li> <li>Added <code>fcntl()</code> function</li> </ul>	
December 2004 v1.2	Updated names of DMA generic requests.	
September 2004 v1.1	<ul style="list-style-type: none"> <li>Added <code>open()</code>.</li> <li>Added <code>ERRNO</code> information to <code>alt_dma_txchan_open()</code>.</li> <li>Corrected <code>ALT_DMA_TX_STREAM_ON</code> definition.</li> <li>Corrected <code>ALT_DMA_RX_STREAM_ON</code> definition.</li> <li>Added information to <code>alt_dma_rxchan_ioctl()</code> and <code>alt_dma_txchan_ioctl()</code>.</li> </ul>	
May 2004 v1.0	Initial Release.	



## Introduction

This chapter provides a complete reference of all available commands, options, and settings for the Nios® II Software Build Tools. This reference is useful for developing your own software projects, packages, or device drivers.



Before using this chapter, read the *Getting Started from the Command Line* chapter of the *Nios II Software Developer's Handbook*, and familiarize yourself with the parts of the *Nios II Software Build Tools* chapter of the *Nios II Software Developer's Handbook* that are relevant to your tasks.

This chapter includes the following sections:

- “Nios II Software Build Tools Utilities” on page 15–1
- “Nios II Example Design Scripts” on page 15–24
- “Settings” on page 15–27
- “Application and User Library Makefile Variables” on page 15–65
- “Tcl Commands” on page 15–68
- “Path Names” on page 15–106

## Nios II Software Build Tools Utilities

The build tools utilities are an entry point to the Nios II Software Build Tools. Everything you can do with the tools, such as specifying settings, creating makefiles, and building projects, is made available by the utilities.

All Nios II Software Build Tools utilities share the following behavior:

- Sends error messages and warning messages to `stderr`.
- Sends normal messages (other than errors and warnings) to `stdout`.
- Displays one error message for each error.
- Returns an exit value of 1 if it detects any errors.
- Returns an exit value of 0 if it does not detect any errors. (Warnings are not errors.)
- If the `help` or `version` command-line option is specified, returns an exit value of 0, and takes no other action. Sends the output (help or version number) to `stdout`.
- If no command-line arguments are specified, returns an exit value of 1 and sends a help message to `stderr`. All commands require at least one argument.
- When an error is detected, suppresses all subsequent operations (such as writing files).

## Logging Levels

All the utilities support multiple status-logging levels. You specify the logging level on the command line. [Table 15-1](#) shows the logging levels supported. At each level, the utilities report the status as listed under **Description**. Each level includes the messages from all lower levels.

**Table 15-1.** Nios II Software Build Tools Logging Levels

Logging Level	Description
silent (lowest)	No information is provided except for errors and warnings (sent to <code>stderr</code> ).
default	Minimal information is provided (for example, start and stop operation of Software Build Tools phases).
verbose	Detailed information is provided (for example, lists of files written).
debug (highest)	Debug information is provided (for example, stack backtraces on errors). This level is for reporting problems to Altera.

[Table 15-2](#) shows the command-line options used to select each logging level. Only one logging level is possible at a time, so these options are all mutually exclusive.

**Table 15-2.** Selecting Logging Level

Command-Line Option	Logging Level	Comments
none	default	If there is no command-line option, the default level is selected.
<code>--silent</code>	silent	Selects silent level of logging.
<code>--verbose</code>	verbose	Selects verbose level of logging.
<code>--debug</code>	debug	Selects debug level of logging.
<code>--log &lt;fname&gt;</code>	debug	All information is written to <code>&lt;fname&gt;</code> in addition to being sent to the <code>stdout</code> and <code>stderr</code> devices.

## Setting Values

The value of a setting is specified with the `--set` command-line option to **nios2-bsp-create-settings** or **nios2-bsp-update-settings**, or with the `set_setting` Tcl command. The value of a setting is obtained with the `--get` command-line option to **nios2-bsp-query-settings** or with the `get_setting` Tcl command.

For more information about settings values and formats, refer to [“Settings” on page 15-27](#).

## Utility and Script Summary

The following command-line utilities and scripts are available:

- [“nios2-app-generate-makefile”](#)
- [“nios2-bsp-create-settings” on page 15-5](#)
- [“nios2-bsp-generate-files” on page 15-6](#)
- [“nios2-bsp-query-settings” on page 15-7](#)
- [“nios2-bsp-update-settings” on page 15-8](#)

- “nios2-lib-generate-makefile” on page 15-10
- “nios2-bsp-editor” on page 15-11
- “nios2-app-update-makefile” on page 15-12
- “nios2-lib-update-makefile” on page 15-14
- “nios2-swexample-create” on page 15-17
- “nios2-elf-insert” on page 15-17
- “nios2-elf-query” on page 15-18
- “nios2-convert-ide2sbt” on page 15-19
- “nios2-c2h-generate-makefile” on page 15-22
- “nios2-bsp” on page 15-23

## nios2-app-generate-makefile

### Usage

```
nios2-app-generate-makefile [--app-dir <directory>]
  --bsp-dir <directory> [--debug]
  [--elf-name <filename>] [--extended-help] [--help]
  [--log <filename>] [--no-src] [--set <name> <value>]
  [--silent] [--src-dir <directory>]
  [--src-files <filenames>] [--src-rdir <directory>]
  [--use-lib-dir <directory>] [--verbose]
  [--version] [--c2h]
```

### Options

- `--app-dir <directory>`: Directory to place the application makefile and executable and linking format file (.elf). If omitted, it defaults to the current directory.
- `--bsp-dir <directory>`: Specifies the path to the BSP generated files directory (populated using the **nios2-bsp-generate-files** command).
- `--debug`: Output debug, exception traces, verbose, and default information about the command's operation to stdout.
- `--elf-name <filename>`: Name of the .elf file to create. If omitted, it defaults to the first source file specified with the file name extension replaced with .elf and placed in the application directory.
- `--extended-help`: Displays full information about this command and its options.
- `--help`: Displays basic information about this command and its options.
- `--log <filename>`: Create a debug log and write to specified file. Also logs debug information to stdout.
- `--no-src`: Allows no sources files to be set in the Makefile. User must add source files in manually before compiling

- `--set <name> <value>`: Set the makefile variable called `<name>` to `<value>`. If the variable exists in the managed section of the makefile, `<value>` replaces the default settings. If the variable does not already exist, it is added. Multiple `--set` options are allowed.
- `--silent`: Suppress information about the command's operation normally sent to stdout.
- `--src-dir <directory>`: Searches for source files in `<directory>`. Use `.` to look in the current directory. Multiple `--src-dir` options are allowed.
- `--src-files <filenames>`: Adds a list of space-separated source file names to the makefile. The list of file names is terminated by the next option or the end of the command line. Multiple `--src-files` options are allowed.
- `--src-rdir <directory>`: Same as `--src-dir` option but recursively search for source files in or under `<directory>`. Multiple `--src-rdir` options are allowed and can be freely mixed with `--src-dir` options.
- `--use-lib-dir <directory>`: Specifies the path to a dependent user library directory. The user library directory must contain a makefile fragment called **public.mk**. Multiple `--use-lib-dir` options are allowed.
- `--verbose`: Output verbose, and default information about the command's operation to stdout.
- `--version`: Displays the version of this command and exits with a zero exit status.

### Description

The **nios2-app-generate-makefile** command generates an application makefile (called Makefile). The path to a BSP created by **nios2-bsp-generate-files** is a mandatory command-line option.

You can enable support for the Nios II C2H Compiler with the `--c2h` option, which creates a null C2H makefile fragment in your project, and includes it in the application makefile. This makefile fragment, `c2h.mk`, contains comments to help you fill in the makefile variables by hand.



This **c2h.mk** overwrites any existing **c2h.mk**.

You can use the command-line tool **nios2-c2h-generate-makefile** to generate a populated C2H makefile fragment.



The **nios2-c2h-generate-makefile** script is available to support pre-existing command-line C2H projects. Create new C2H projects using the Nios II IDE.

For more details about this command, use the `--extended-help` option to display comprehensive usage information.

## nios2-bsp-create-settings

### Usage

```
nios2-bsp-create-settings [--bsp-dir <directory>]
  [--cmd <tcl command>] [--cpu-name <cpu name>]
  [--debug] [--extended-help] [--help] [--jdi <filename>]
  [--librarian-factory-path <directory>]
  [--librarian-path <directory>] [--log <filename>]
  [--script <filename>] [--set <name> <value>]
  --settings <filename> [--silent]
  --sopc <filename> --type <OS name> [--verbose]
  [--version]
```

### Options

- **--bsp-dir <directory>**: Path to the directory where the BSP files are generated. Use `.` for the current directory. The directory *<directory>* must exist. This command overwrites preexisting files in *<directory>* without warning.
- **--cmd <tcl command>**: Runs the specified Tcl command. Multiple **--cmd** options are allowed.
- **--cpu-name <cpu name>**: The name of the Nios II processor that the BSP supports. Optional for a single-processor SOPC Builder system.
- **--debug**: Sends debug information, exception traces, verbose output, and default information about the command's operation, to stdout.
- **--extended-help**: Displays full information about this command and its options.
- **--help**: Displays basic information about this command and its options.
- **--jdi <filename>**: The location of the JTAG Debugging Information File (**.jdi**) generated by the Quartus® II software. The **.jdi** file specifies the name-to-node mappings for the JTAG chain elements. The tool inserts the **.jdi** path in **public.mk**. If no **.jdi** path is specified, the command searches the directory containing the **.sopcinfo** file, and uses the first **.jdi** file found.
- **--librarian-factory-path <directory>**: Comma separated librarian search path. Use `$` for default factory search path.
- **--librarian-path <directory>**: Comma separated librarian search path. Use `$` for default search path.
- **--log <filename>**: Creates a debug log and write to specified file. Also logs debug information to stdout.
- **--script <filename>**: Run the specified Tcl script with optional arguments. Multiple **--script** options are allowed.
- **--set <name> <value>**: Sets the setting called *<name>* to *<value>*. Multiple **--set** options are allowed.
- **--settings <filename>**: File name of the BSP settings file to create. This file is created with a **.bsp** file extension. It overwrites any existing settings file.
- **--silent**: Suppresses information about the command's operation normally sent to stdout.

- `--sopc <filename>`: The SOPC Information File (**.sopcinfo**) used to create the BSP.
- `--type <OS name>`: BSP type. Use ? to list available BSP types for this option.
- `--verbose`: Sends verbose output, and default information about the command's operation, to stdout.
- `--version`: Displays the version of this command and exits with a zero exit status.

### Description

If you use **nios2-bsp-create-settings** to create a settings file without any command-line options, Tcl commands, or Tcl scripts to modify the default settings, it creates a settings file that fails when running **nios2-bsp-generate-files**. Failure occurs because the **nios2-bsp-create-settings** command is able to create reasonable defaults for most settings, but the command requires additional information for system-dependent settings. The default Tcl scripts set the required system-dependent settings. Therefore it is better to use default Tcl scripts when calling **nios2-bsp-create-settings** directly. For an example of how to use the default Tcl scripts, refer to the **nios2-bsp** script.

For more details about this command, use the `--extended-help` option to display comprehensive usage information.

### Example

```
nios2-bsp-create-settings --settings my_settings.bsp --sopc \
    ../my_sopc.sopcinfo --type hal --script default_settings.tcl
```

## nios2-bsp-generate-files

### Usage

```
nios2-bsp-generate-files --bsp-dir <directory>
    [--debug] [--extended-help] [--help]
    [--librarian-factory-path <directory>]
    [--librarian-path <directory>] [--log <filename>]
    --settings <filename> [--silent] [--verbose]
    [--version]
```

### Options

- `--bsp-dir <directory>`: Path to the directory where the BSP files are generated. Use . for the current directory. The directory *<directory>* must exist. This command overwrites preexisting files in *<directory>* without warning.
- `--debug`: Sends debug, exception trace, verbose, and default information about the command's operation to stdout.
- `--extended-help`: Displays full information about this command and its options.
- `--help`: Displays basic information about this command and its options.
- `--librarian-factory-path <directory>`: Comma separated librarian search path. Use \$ for default factory search path.



- `--librarian-path <directory>`: Comma separated librarian search path. Use \$ for default search path.
- `--log <filename>`: Creates a debug log and writes to specified file. Also logs debug information to stdout.
- `--settings <filename>`: File name of an existing BSP Settings File (**.bsp**) to generate files from.
- `--silent`: Suppresses information about the command's operation normally sent to stdout.
- `--verbose`: Sends verbose and default information about the command's operation to stdout.
- `--version`: Displays the version of this command and exits with a zero exit status.

### Description

The **nios2-bsp-generate-files** command populates the files in a BSP directory. The path to an existing **.bsp** file and the path to the BSP directory are mandatory command-line options. Files are written to the specified BSP directory. Generated files are created unconditionally. Copied files are copied from the Nios II EDS installation folder only if they are not present in the BSP directory, or if the existing files differ from the installation files.

```
--set APP_INCLUDE_DIRS \"lcd board\"
```

For more details about this command, use the `--extended-help` option to display comprehensive usage information.

## nios2-bsp-query-settings

### Usage

```
nios2-bsp-query-settings [--cmd <tcl command>]
  [--debug] [--extended-help] [--get <name>]
  [--get-all] [--help]
  [--librarian-factory-path <directory>]
  [--librarian-path <directory>] [--log <filename>]
  [--script <filename>] --settings <filename>
  [--show-descriptions] [--show-names] [--silent]
  [--verbose] [--version]
```

### Options

- `--cmd <tcl command>`: Run the specified Tcl command. Multiple `--cmd` options are allowed.
- `--debug`: Output debug, exception traces, verbose, and default information about the command's operation to stdout.
- `--extended-help`: Displays full information about this command and its options.
- `--get <name>`: Display the value of the setting called `<name>`. Multiple `--get` options are allowed. Each value appears on its own line in the order the `--get` options are specified. Mutually exclusive with the `--get-all` option.

- `--get-all`: Display the value of all BSP settings in order sorted by option name. Each option appears on its own line. Mutually exclusive with the `--get` option.
- `--help`: Displays basic information about this command and its options.
- `--librarian-factory-path <directory>`: Comma separated librarian search path. Use `$` for default factory search path.
- `--librarian-path <directory>`: Comma separated librarian search path. Use `$` for default search path.
- `--log <filename>`: Create a debug log and write to specified file. Also logs debug information to stdout.
- `--script <filename>`: Run the specified Tcl script with optional arguments. Multiple `--script` options are allowed.
- `--settings <filename>`: File name of an existing BSP settings file to query settings from.
- `--show-descriptions`: Displays the description of each option after the value.
- `--show-names`: Displays the name of each option before the value.
- `--silent`: Suppress information about the command's operation normally sent to stdout.
- `--verbose`: Output verbose, and default information about the command's operation to stdout.
- `--version`: Displays the version of this command and exits with a zero exit status.

### Description

The **nios2-bsp-query-settings** command provides information from a .bsp file. The path to an existing .bsp file is a mandatory command-line option. The command does not modify the settings file. Only information requested by the user is displayed on stdout; no informational messages are displayed.

For more details about this command, use the `--extended-help` option to display comprehensive usage information.

## nios2-bsp-update-settings

### Usage

```
nios2-bsp-update-settings [--bsp-dir <directory>]
  [--cmd <tcl command>] [--cpu-name <cpu name>]
  [--debug] [--extended-help] [--help] [--jdi <filename>]
  [--librarian-factory-path <directory>]
  [--librarian-path <directory>] [--log <filename>]
  [--script <filename>] [--set <name> <value>]
  --settings <filename> [--silent]
  [--sopc <filename>] [--verbose] [--version]
```

### Options

- `--bsp-dir <directory>`: Path to the directory where the BSP files are generated. Use `.` for the current directory. The directory `<directory>` must exist.

- `--cmd <tcl command>`: Run the specified Tcl command. Multiple `--cmd` options are allowed.
- `--cpu-name <cpu name>`: The name of the Nios II processor that the BSP supports. This argument is useful if the SOPC Builder design contains multiple Nios II processors. Optional for single-processor SOPC Builder design.
- `--debug`: Output debug, exception traces, verbose, and default information about the command's operation to stdout.
- `--extended-help`: Displays full information about this command and its options.
- `--help`: Displays basic information about this command and its options.
- `--jdi <filename>`: The location of the **.jdi** file generated by the Quartus II software. The **.jdi** file specifies the name-to-node mappings for the JTAG chain elements. The tool inserts the **.jdi** path in **public.mk**. If no **.jdi** path is specified, the command searches the directory containing the **.sopcinfo** file, and uses the first **.jdi** file found.
- `--librarian-factory-path <directory>`: Comma separated librarian search path. Use `$` for default factory search path.
- `--librarian-path <directory>`: Comma separated librarian search path. Use `$` for default search path.
- `--log <filename>`: Create a debug log and write to specified file. Also logs debug information to stdout.
- `--script <filename>`: Run the specified Tcl script with optional arguments. Multiple `--script` options are allowed.
- `--set <name> <value>`: Set the setting called `<name>` to `<value>`. Multiple `--set` options are allowed.
- `--settings <filename>`: File name of an existing BSP settings file to update.
- `--silent`: Suppress information about the command's operation normally sent to stdout.
- `--sopc <filename>`: The **.sopcinfo** file to update the BSP with. It is recommended to create a new BSP if the design has changed significantly. This argument is useful if the path to the original **.sopcinfo** file has changed.
- `--verbose`: Output verbose, and default information about the command's operation to stdout.
- `--version`: Displays the version of this command and exits with a zero exit status.

## Description

The **nios2-bsp-update-settings** command updates an existing Nios II **.bsp** file. The path to an existing **.bsp** file is a mandatory command-line option. The command modifies the settings file so the file must have write permissions. You might want to use the `--script` option to pass the default Tcl script to the **nios2-bsp-update-settings** command to make sure that your BSP is consistent with your SOPC Builder system (this is what the **nios2-bsp** command does).

For more details about this command, use the `--extended-help` option to display comprehensive usage information.

## nios2-lib-generate-makefile

### Usage

```
nios2-lib-generate-makefile [--bsp-dir <directory>]
  [--debug] [--extended-help] [--help]
  [--lib-dir <directory>] [--lib-name <filename>]
  [--log <filename>] [--no-src]
  [--public-inc-dir <directory>] [--set <name> <value>]
  [--silent] [--src-dir <directory>]
  [--src-files <filenames>] [--src-rdir <directory>]
  [--use-lib-dir <directory>] [--verbose]
  [--version]
```

### Options

- `--bsp-dir <directory>`: Path to the BSP generated files directory (populated using the **nios2-bsp-generate-files** command).
- `--debug`: Output debug, exception traces, verbose, and default information about the command's operation to stdout.
- `--extended-help`: Displays full information about this command and its options.
- `--help`: Displays basic information about this command and its options.
- `--lib-dir <directory>`: Destination directory for the user library archive file (**.a**), the user library makefile, and **public.mk**. If omitted, it defaults to the current directory.
- `--lib-name <filename>`: Name of the user library being created. The user library file name is the user library name with a **lib** prefix and **.a** suffix added so don't include these in the user library name itself. If the user library name option is omitted, the user library name defaults to the name of the first source file with its extension removed.
- `--log <filename>`: Create a debug log and write to specified file. Also logs debug information to stdout.
- `--no-src`: Allows no sources files to be set in the Makefile. User must add source files in manually before compiling
- `--public-inc-dir <directory>`: Path to a directory that contains C header files (**.h**) that should made available (that is, public) to users of the user library. This directory is added to the appropriate variable in **public.mk**. Multiple `--public-inc-dir` options are allowed.
- `--set <name> <value>`: Set the makefile variable called `<name>` to `<value>`. If the variable exists in the managed section of the makefile, `<value>` replaces the default settings. It adds the makefile variable if it does not already exist. Multiple `--set` options are allowed.
- `--silent`: Suppress information about the command's operation normally sent to stdout.

- `--src-dir <directory>`: Search for source files in *<directory>*. Use `.` to look in the current directory. Multiple `--src-dir` options are allowed.
- `--src-files <filenames>`: A list of space-separated source file names added to the makefile. The list of file names is terminated by the next option or the end of the command line. Multiple `--src-files` options are allowed.
- `--src-rdir <directory>`: Same as `--src-dir` option but recursively search for source files in or under *<directory>*. Multiple `--src-rdir` options are allowed and can be freely mixed with `--src-dir` options.
- `--use-lib-dir <directory>`: Path to a dependent user library directory. The user library directory must contain a makefile fragment called **public.mk**. Multiple `--use-lib-dir` options are allowed.
- `--verbose`: Output verbose, and default information about the command's operation to stdout.
- `--version`: Displays the version of this command and exits with a zero exit status.

### Description

The **nios2-lib-generate-makefile** command generates a user library makefile (called Makefile). The path to a BSP created by **nios2-bsp-generate-files** is an optional command-line option.

For more details about this command, use the `--extended-help` option to display comprehensive usage information.

## nios2-bsp-editor

### Usage

```
nios2-bsp-editor [--extended-help]
                [--fontsize <point size>] [--help]
                [--librarian-factory-path <directory>]
                [--librarian-path <directory>] [--log <filename>]
                [--settings <filename>] [--version]
```

### Options

- `--extended-help`: Displays full information about this command and its options.
- `--fontsize <point size>`: The default point size for GUI fonts is 11. Use this option to adjust the point size.
- `--help`: Displays basic information about this command and its options.
- `--librarian-factory-path <directory>`: Comma separated librarian search path. Use `$` for default factory search path.
- `--librarian-path <directory>`: Comma separated librarian search path. Use `$` for default search path.
- `--log <filename>`: Create a debug log and write to specified file.
- `--settings <filename>`: File name of an existing BSP settings file to update.

- `--version`: Displays the version of this command and exits with a zero exit status.

### Description

The **nios2-bsp-editor** command is a GUI application for creating and editing board support packages for Nios II designs.

For more details about this command, use the `--extended-help` option to display comprehensive usage information.

## nios2-app-update-makefile

### Usage

```
nios2-app-update-makefile --app-dir <directory>
  [--add-lib-dir <directory>] [--add-src-dir <directory>]
  [--add-src-files <filenames>] [--add-src-rdir <directory>] [--debug]
  [--extended-help] [--force] [--get <name>] [--get-all]
  [--get-asflags] [--get-bsp-dir] [--get-debug-level]
  [--get-defined-symbols] [--get-elf-name] [--get-optimization]
  [--get-undefined-symbols] [--get-user-flags] [--get-warnings]
  [--help] [--list-lib-dir] [--list-src-files] [--lock]
  [--log <filename>] [--no-src] [--remove-lib-dir <directory>]
  [--remove-src-dir <directory>] [--remove-src-files <filenames>]
  [--remove-src-rdir <directory>] [--set <name>]
  [--set-asflags <value>] [--set-bsp-dir <directory>]
  [--set-debug-level <value>] [--set-defined-symbols <value>]
  [--set-elf-name <name>] [--set-optimization <value>]
  [--set-undefined-symbols <value>] [--set-user-flags <value>]
  [--set-warnings <value>] [--show-managed-section] [--show-names]
  [--silent] [--unlock] [--verbose] [--version]
```

### Options

- `--app-dir <directory>`: Path to the Application Directory with the generated makefile.
- `--add-lib-dir <directory>`: Add a path to dependent user library directory
- `--add-src-dir <directory>`: Add source files in `<directory>`. Use `.` to look in the current directory. Multiple `--add-src-dir` options are allowed.
- `--add-src-files <filenames>`: A list of space-separated source file names to be added to the makefile. The list of file names is terminated by the next option or the end of the command line. Multiple `--src-files` options are allowed.
- `--add-src-rdir <directory>`: Same as `--add-src-dir` option but recursively search for source files in or under `<directory>`. Multiple `--add-src-rdir` options are allowed and can be freely mixed with `--src-dir` options.
- `--debug`: Output debug, exception traces, verbose, and default information about the command's operation to stdout.
- `--extended-help` Displays full information about this command and its options.
- `--force`: Update the Makefile even if it's locked
- `--get <name>`: Get the values of Makefile variables

- `--get-all` Get all variables in the managed section of the Makefile
- `--get-asflags` Get user assembler flags
- `--get-bsp-dir` Get the BSP generated files directory
- `--get-debug-level` Get debug level flag
- `--get-defined-symbols` Get defined symbols flag
- `--get-elf-name` Get the name of .elf file
- `--get-optimization` Get optimization flag
- `--get-undefined-symbols` Get undefined symbols flag
- `--get-user-flags` Get user flags
- `--get-warnings` Get warnings flag
- `--help`: Displays basic information about this command and its options.
- `--list-lib-dir` List all paths to dependent user library directories
- `--list-src-files` List all source files in the makefile.
- `--lock`: Lock the Makefile to prevent it from being updated
- `--log <filename>`: Create a debug log and write to specified file. Also logs debug information to stdout.
- `--no-src` Remove all source files in the makefile
- `--remove-lib-dir <directory>`: Remove a path to dependent user library directory
- `--remove-src-dir <directory>`: Remove source files in <directory>. Use . to look in the current directory. Multiple `--remove-src-dir` options are allowed.
- `--remove-src-files <filenames>`: A list of space-separated source file names to be removed from the makefile. The list of file names is terminated by the next option or the end of the command line. Multiple `--src-files` options are allowed.
- `--remove-src-rdir <directory>`: Same as `--remove-src-dir` option but recursively search for source files in or under <directory>. Multiple `--remove-src-rdir` options are allowed and can be freely mixed with `--src-dir` options.
- `--set <name> <value>`: Set the value of a Makefile variable called <name>
- `--set-asflags <value>`: Set user assembler flags
- `--set-bsp-dir <directory>`: Set the BSP generated files directory
- `--set-debug-level <value>`: Set debug level flag
- `--set-defined-symbols <value>`: Set defined symbols flag
- `--set-elf-name <name>`: Set the name of .elf file
- `--set-optimization <value>`: Set optimization flag
- `--set-undefined-symbols <value>`: Set undefined symbols flag
- `--set-user-flags <value>`: Set user flags

- `--set-warnings <value>`: Set warnings flag
- `--show-managed-section` Show the managed section in the Makefile
- `--show-names` Show name of the variables
- `--silent`: Suppress information about the command's operation normally sent to stdout.
- `--unlock`: Unlock the Makefile
- `--verbose`: Output verbose, and default information about the command's operation to stdout.
- `--version`: Displays the version of this command and exits with a zero exit status.

### Description

The **nios2-app-update-makefile** command updates an application makefile to add or remove source files.

For more details about this command, use the `--extended-help` option to display comprehensive usage information.



The `--add-src-dir`, `--add-src-rdir`, `--remove-src-dir`, and `--remove-src-rdir` options add and remove files found in *<directory>* at the time the command is executed. Files subsequently added to or removed from the directory are not reflected in the makefile.

## nios2-lib-update-makefile

### Usage

```
nios2-lib-update-makefile --lib-dir <directory>
[--add-lib-dir <directory>] [--add-public-inc-dir <directory>]
[--add-src-dir <directory>] [--add-src-files <filenames>]
[--add-src-rdir <directory>] [--debug] [--extended-help] [--force]
[--get <name>] [--get-all] [--get-asflags] [--get-bsp-dir]
[--get-debug-level] [--get-defined-symbols] [--get-lib-name]
[--get-optimization] [--get-undefined-symbols] [--get-user-flags]
[--get-warnings] [--help] [--list-lib-dir] [--list-public-inc-dir]
[--list-src-files] [--lock] [--log <filename>] [--no-src]
[--remove-lib-dir <directory>] [--remove-public-inc-dir <directory>]
[--remove-src-dir <directory>] [--remove-src-files <filenames>]
[--remove-src-rdir <directory>] [--set <name> <value>]
[--set-asflags <value>] [--set-bsp-dir <directory>]
[--set-debug-level <value>] [--set-defined-symbols <value>]
[--set-lib-name <name>] [--set-optimization <value>]
[--set-undefined-symbols <value>] [--set-user-flags <value>]
[--set-warnings <value>] [--show-managed-section] [--show-names]
[--silent] [--unlock] [--verbose] [--version]
```

### Options

- `--add-lib-dir <directory>`: Add a path to dependent user library directory
- `--add-public-inc-dir <directory>`: Add a directory that contains C-language header files



- `--add-src-dir <directory>`: Add source files in *<directory>*. Use `.` to look in the current directory. Multiple `--add-src-dir` options are allowed.
- `--add-src-files <filenames>`: A list of space-separated source file names to be added to the makefile. The list of file names is terminated by the next option or the end of the command line. Multiple `--src-files` options are allowed.
- `--add-src-rdir <directory>`: Same as `--add-src-dir` option but recursively search for source files in or under *<directory>*. Multiple `--add-src-rdir` options are allowed and can be freely mixed with `--src-dir` options.
- `--debug`: Output debug, exception traces, verbose, and default information about the command's operation to stdout.
- `--extended-help`: Displays full information about this command and its options.
- `--force`: Update the Makefile even if it's locked
- `--get <name>`: Get the values of Makefile variables
- `--get-all`: Get all variables in the managed section of the Makefile
- `--get-asflags`: Get user assembler flags
- `--get-bsp-dir`: Get the BSP generated files directory
- `--get-debug-level`: Get debug level flag
- `--get-defined-symbols`: Get defined symbols flag
- `--get-lib-name`: Get the name of user library
- `--get-optimization`: Get optimization flag
- `--get-undefined-symbols`: Get undefined symbols flag
- `--get-user-flags`: Get user flags
- `--get-warnings`: Get warnings flag
- `--help`: Displays basic information about this command and its options.
- `--list-lib-dir`: List all paths to dependent user library directories
- `--list-public-inc-dir`: List all public include directories
- `--list-src-files`: List all source files in the makefile.
- `--lock`: Lock the Makefile to prevent it from being updated
- `--log <filename>`: Create a debug log and write to specified file. Also logs debug information to stdout.
- `--no-src`: Remove all source files
- `--remove-lib-dir <directory>`: Remove a path to dependent user library directory
- `--remove-public-inc-dir <directory>`: Remove a include directory
- `--remove-src-dir <directory>`: Remove source files in *<directory>*. Use `.` to look in the current directory. Multiple `--remove-src-dir` options are allowed.

- `--remove-src-files <filenames>`: A list of space-separated source file names to be removed from the makefile. The list of file names is terminated by the next option or the end of the command line. Multiple `--src-files` options are allowed.
- `--remove-src-rdir <directory>`: Same as `--remove-src-dir` option but recursively search for source files in or under `<directory>`. Multiple `--remove-src-rdir` options are allowed and can be freely mixed with `--src-dir` options.
- `--set <name> <value>`: Set the value of a Makefile variable called `<name>`
- `--set-asflags <value>`: Set user assembler flags
- `--set-bsp-dir <directory>`: Set the BSP generated files directory
- `--set-debug-level <value>`: Set debug level flag
- `--set-defined-symbols <value>`: Set defined symbols flag
- `--set-lib-name <name>`: Set the name of user library
- `--set-optimization <value>`: Set optimization flag
- `--set-undefined-symbols <value>`: Set undefined symbols flag
- `--set-user-flags <value>`: Set user flags
- `--set-warnings <value>`: Set warnings flag
- `--show-managed-section`: Show the managed section in the Makefile
- `--show-names`: Show name of the variables
- `--silent`: Suppress information about the command's operation normally sent to stdout.
- `--unlock`: Unlock the Makefile
- `--verbose`: Output verbose, and default information about the command's operation to stdout.
- `--version`: Displays the version of this command and exits with a zero exit status.

### Description

The **nios2-lib-update-makefile** command updates a user library makefile to add or remove source files.

For more details about this command, use the `--extended-help` option to display comprehensive usage information.



The `--add-src-dir`, `--add-src-rdir`, `--remove-src-dir`, and `--remove-src-rdir` options add and remove files found in `<directory>` at the time the command is executed. Files subsequently added to or removed from the directory are not reflected in the makefile.

## nios2-swexample-create

### Usage

```
nios2-create-swexample [--name] --sopc-dir --type [--list] [--app-dir]
  [--bsp-dir] [--no-app] [--no-bsp] [--elf-name] [--describe]
  [--describeX] [--describeAll] [--search] [--help] [--silent]
  [--version]
```

### Options

- **--name**: Specify the name of the software project to create.
- **--sopc-dir** Specify the SOPC builder directory. Required.
- **--type**: Specify the software example design template type. Required.
- **--list**: List all valid software example design template types.
- **--app-dir**: Specify the application directory to create. Default: *<sopc-dir>/software\_examples/app/<name>*
- **--bsp-dir**: Specify the bsp directory to create. Default: *<sopc-dir>/software\_examples/bsp/<bsp-type>*
- **--no-app** Do not generate the **create-this-app** script
- **--no-bsp** Do not generate the **create-this-bsp** script
- **--elf-name** Name of the .elf file to create.
- **--describe**: Describe the software example type specified and exit.
- **--describeX**: Verbosely describe the software example type specified and exit.
- **--describeAll**: Describe all the software example types and exit.
- **--search**: Search for software example templates in the specified directory. Default: *\$SOPC\_KIT\_NIOS2/examples/software*
- **--help**: Displays basic information about this command and its options.
- **--silent**: Do not echo commands.
- **--version**: Print the version number of nios2-create-swexample and exit.

### Description

This utility creates a template software example for a given SOPC system.

## nios2-elf-insert

### Usage

```
nios2-elf-insert <filename> [--cpu_name <cpuName>]
  [--stderr_dev <stderrDev>] [--stdin_dev <stdinDev>]
  [--stdout_dev <stdoutDev>] [--sidp <sysidBase>] [--id <sysidHash>]
  [--timestamp <sysidTime>] [--sof <sofFile>]
  [--sopcinfo <sopcinfoFile>] [--jar <jarFile>] [--jdi <jdiFile>]
  [--quartus_project_dir <quartusProjectDir>]
  [--sopc_system_name <sopcSystemName>]
  [--profiling_enabled <profilingEnabled>]
  [--simulation_enabled <simulationEnabled>]
```

## Options

- *<filename>*: the ELF filename
- `--cpu_name <cpuName>`
- `--stderr_dev <stderrDev>`
- `--stdin_dev <stdinDev>`
- `--stdout_dev <stdoutDev>`
- `--sidp <sysidBase>`
- `--id <sysidHash>`
- `--timestamp <sysidTime>`
- `--sof <sofFile>`
- `--sopcinfo <sopcinfoFile>`
- `--jar <jarFile>`
- `--jdi <jdiFile>`
- `--quartus_project_dir <quartusProjectDir>`
- `--sopc_system_name <sopcSystemName>`
- `--profiling_enabled <profilingEnabled>`
- `--simulation_enabled <simulationEnabled>`

## nios2-elf-query

### Usage

```
nios2-elf-query <filename> [--cpu_name] [--stderr_dev] [--stdin_dev]
  [--stdout_dev] [--sidp] [--id] [--timestamp] [--sof] [--sopcinfo]
  [--jar] [--jdi] [--quartus_project_dir] [--sopc_system_name]
  [--profiling_enabled] [--simulation_enabled]
```

### Options

- *<filename>*: the ELF filename
- `--cpu_name`
- `--stderr_dev`
- `--stdin_dev`
- `--stdout_dev`
- `--sidp`
- `--id`
- `--timestamp`
- `--sof`
- `--sopcinfo`
- `--jar`

- `--jdi`
- `--quartus_project_dir`
- `--sopc_system_name`
- `--profiling_enabled`
- `--simulation_enabled`

## nios2-convert-ide2sbt

### Usage

```
nios2-convert-ide2sbt --input-dir --output-dir [--build-config]
  [--help] [--silent] [--version]
```

### Options

- `--input-dir`: Specify the input application project directory to create. Required.
- `--output-dir`: Specify the directory to create your output projects. Required.
- `--build-config`: Specify the build configuration type: for example Release, Debug.
- `--help`: Print this message and exit.
- `--silent`: Suppress information about the command's operation normally sent to stdout.
- `--version`: Displays the version of this command and exits.

### Description

Convert a Nios II IDE project to a Nios II Software Build Tools project.

## nios2-flash-programmer-generate

### Usage

```
nios2-flash-programmer-generate [--accept-bad-sysid]
  [--add-bin <fname> <flash-slave-desc> <offset>]
  [--add-elf <fname> <flash-slave-desc> <extra-elf2flash-arguments>]
  [--add-sof <fname> <flash-slave-desc> <offset>
  <extra-sof2flash-arguments>]
  [--cable <cable name>] [--cpu <cpu name>] [--debug]
  [--device <device name>] [--erase-first] [--extended-help]
  --flash-dir <directory> [--go] [--help] [--id <address>]
  [--instance <instance value>] [--log <filename>] [--mmu]
  [--program-flash] [--script-dir <directory>] [--sidp <address>]
  [--silent] --sopcinfo <filename> [--verbose] [--version]
```

### Options

- `--accept-bad-sysid`: Continue even if the system identifier (ID) comparison fails.
- `--add-bin <fname> <flash-slave-desc> <offset>`: Specify a binary file to convert and program. The filename, target flash slave descriptor, and target offset amount are required. This option can be used multiple times for `.sof` files.

- `--add-elf <fname> <flash-slave-desc>`  
`<extra-elf2flash-arguments>`: Specify a **.elf** file to convert and program. The filename and target flash slave descriptor are required. This option can be used multiple times for **.elf** files. `<extra-elf2flash-arguments>` can be any of the following options supported by **elf2flash**:
  - `save`
  - `sim_optimize`

The following **elf2flash** options have default values computed, but are also supported as `<extra-elf2flash-arguments>` for manual override of those defaults:

  - `base`
  - `boot`
  - `end`
  - `reset`
- `--add-sof <fname> <flash-slave-desc> <offset>`  
`<extra-sof2flash-arguments>`: Specify a **.sof** file to convert and program. The filename, target flash slave descriptor, and target offset arguments are required. This option can be used multiple times for **.sof** files. `<extra-sof2flash-arguments>` can be any of the following options supported by **sof2flash**:
  - `activeparallel`
  - `compress`
  - `save`
  - `timestamp`
  - `options`
- `--cable <cable name>`: Specifies which JTAG cable to use (not needed if you only have one cable). Not used without `--program-flash` option.
- `--cpu <cpu name>`: The SOPC Builder system file Nios II processor name. Not required if only one Nios II processor in the system.
- `--debug`: Sends debug information, exception traces, verbose output, and default information about the command's operation, to stdout.
- `--device <device name>`: Specifies in which device you want to look for the Nios II debug core. Device 1 is the device nearest TDI. Not used without `--program-flash` option.
- `--erase-first`: Erase entire flash targets before programming them. Not used without `--program-flash` option.
- `--extended-help`: Displays full information about this command and its options.
- `--flash-dir <directory>`: Path to the directory where the flash files are generated. Use `.` for the current directory. This command overwrites pre-existing files in `<directory>` without warning.
- `--go`: Run processor from reset vector after program.

- `--help`: Displays basic information about this command and its options.
- `--id <address>`: Unique ID code for target system. Not used without `--program-flash` option.
- `--instance <instance value>`: Specifies the INSTANCE value of the debug core (not needed if there is exactly one on the chain). Not used without `--program-flash` option.
- `--log <filename>`: Creates a debug log and write to specified file. Also logs debug information to stdout.
- `--mmu`: Specifies if the processor with the corresponding INSTANCE value has an MMU (not needed if there is exactly one processor in the system). Not used without `--program-flash` option.
- `--program-flash`: Providing this flag causes calls to **nios2-flash-programmer** to be generated and executed. This results in flash targets being programmed.
- `--script-dir <directory>`: Path to the directory where a shell script of this tool's executed command lines is generated. This script can be used in place of this **nios2-flash-programmer-generate** command. Use `.` for the current directory. This command overwrites pre-existing files in `<directory>` without warning.
- `--sidp <address>`: Base address of system ID peripheral on the target. Not used without `--program-flash` option.
- `--silent`: Suppresses information about the command's operation normally sent to stdout.
- `--sopcinfo <filename>`: The **.sopcinfo** file.
- `--verbose`: Sends verbose output, and default information about the command's operation, to stdout.
- `--version`: Displays the version of this command and exits with a zero exit status.

### Description

The **nios2-flash-programmer-generate** command converts multiple files to a **.flash** in Motorola S-record format, and programs them to the designated target flash devices (`--program-flash`). This is a convenience utility that manages calls to the following command line utilities

- **bin2flash**
- **elf2flash**
- **sof2flash**
- **nios2-flash-programmer**

This utility also generates a script that captures the sequence of conversion and flash programmer commands.

### Example

```
nios2-flash-programmer-generate --sopcinfo=C:\my_design.sopcinfo \
--flash-dir=. \
--add-sof C:\my_design\test.sof 0x0C000000 memory_0 compress save \
--add-elf C:\my_app\my_app.elf 0x08000000 memory_0 \
--program-flash
```

## nios2-c2h-generate-makefile

### Usage

```
nios2-c2h-generate-makefile --sopc=<sopc>
--app-dir=<dir>
--accelerator=<function>
--enable_quartus=<0/1>
--analyze_only=<0/1>
--use_existing_accelerators=<0/1>
```

### Options

- **--sopc**: The path to the **.sopcinfo** file.
- **--app-dir**: Directory to place the application Makefile and executable file. If omitted, it defaults to the current directory.
- **--accelerator**: Specifies a function to be accelerated.
- **--enable\_quartus**: Building the application compiles the associated Quartus II project. Defaults to 0.
- **--analyze\_only**: Disables hardware generation, SOPC Builder system generation, and Quartus II compilation for all accelerators in the application. Building the project with this option only updates the report files. Defaults to 0.
- **--use\_existing\_accelerators**: Disables all hardware generation steps. The build behaves as if **c2h.mk** did not exist, with the exception of possible accelerator linking as specified in the **--accelerator** option. Defaults to 0.

### Description

The **nios2-c2h-generate-makefile** command creates a C2H makefile fragment, **c2h.mk**, that specifies all accelerators and accelerator options for an application.

This command creates a new **c2h.mk** each time it is called, overwriting the existing **c2h.mk**

The **--accelerator** argument specifies a function to be accelerated. This argument accepts up to four comma-separated values:

- Target function name.
- Target function file.
- Link hardware accelerator instead of original software. 1 or 0. Defaults to 1.
- Flush data cache before each call. 1 or 0. Defaults to 1.



The **nios2-c2h-generate-makefile** script is available to support pre-existing command-line C2H projects. Create new C2H projects using the Nios II IDE.



### Example

```
nios2-c2h-generate-makefile \  
--sopc=../../NiosII_stratix_ls40_standard.sopcinfo \  
--app_dir=./ \  
--accelerator=filter,filter.c \  
--accelerator=xmath,../../xmath.c,1,0 \  
--use_existing_accelerators
```

## nios2-bsp

### Usage

```
nios2-bsp <bsp-type> <bsp-dir> [<sopc>] [<override>]...
```

### Options

- *<bsp-type>*: hal or ucosii.
- *<bsp-dir>*: Path to the BSP directory.
- *<sopc>*: The path to the **.sopcinfo** file or its directory.
- *<override>*: Options to override defaults.

### Description

The **nios2-bsp** script calls **nios2-bsp-create-settings** or **nios2-bsp-update-settings** to create or update a BSP settings file, and the **nios2-bsp-generate-files** command to create the BSP files. The Nios II Embedded Design Suite (EDS) supports the following BSP types:

- hal
- ucosii

BSP type names are case-insensitive.

This utility produces a BSP of *<bsp-type>* in *<bsp-dir>*. If the BSP does not exist, it is created. If the BSP already exists, it is updated to be consistent with the associated SOPC Builder system.

The default Tcl script is used to set the following system-dependent settings:

- stdio character device
- System timer device
- Default linker memory
- Boot loader status (enabled or disabled)

If the BSP already exists, **nios2-bsp** overwrites these system-dependent settings.

The default Tcl script resides at:

```
<Nios II EDS install path>/sdk2/bin/bsp-set-defaults.tcl
```

When creating a new BSP, this utility runs **nios2-bsp-create-settings**, which creates **settings.bsp** in *<bsp-dir>*.

When updating an existing BSP, this utility runs **nios2-bsp-update-settings**, which updates **settings.bsp** in *<bsp-dir>*.

After creating or updating the **settings.bsp** file, this utility runs **nios2-bsp-generate-files**, which generates files in *<bsp-dir>*

Required arguments:

- *<bsp-type>*: Specifies the type of BSP. This argument is ignored when updating a BSP. This argument is case-insensitive. The **nios2-bsp** script supports the following values of *<bsp-type>*:
  - hal
  - ucosii
- *<bsp-dir>*: Path to the BSP directory. Use "." to specify the current directory.

Optional arguments:

- *<sopc>*: The path name of the **.sopcinfo** file. Alternatively, specify a directory containing a **.sopcinfo** file. In the latter case, the tool finds a file with the extension **.sopcinfo**. This argument is ignored when updating a BSP. If you omit this argument, it defaults to the current directory.
- *<override>*: Options to override defaults. The **nios2-bsp** script passes most overrides to **nios2-bsp-create-settings** or **nios2-bsp-update-settings**. It also passes the **--silent**, **--verbose**, **--debug**, and **--log** options to **nios2-bsp-generate-files**.

**nios2-bsp** passes the following overrides to the default Tcl script:

- **--default\_stdio <device> | none | DONT\_CHANGE**  
Specifies stdio device.
- **--default\_sys\_timer <device> | none | DONT\_CHANGE**  
Specifies system timer device.
- **--default\_memory\_regions DONT\_CHANGE**  
Suppresses creation of new default memory regions when updating a BSP. Do not use this option when creating a new BSP.
- **--default\_sections\_mapping <region> | DONT\_CHANGE**  
Specifies the memory region for the default sections.
- **--use\_bootloader 0 | 1 | DONT\_CHANGE**  
Specifies whether a boot loader is required.

On a preexisting BSP, the value **DONT\_CHANGE** prevents associated settings from changing their current value.



The "--" prefix is stripped when the option is passed to the underlying utility.

## Nios II Example Design Scripts

The Nios II Software Build Tools include scripts that allow you to create sample BSPs and applications. This section describes each script and its location in the example design directory structure. Each hardware example design in the Nios II EDS includes a **software\_examples** directory with **app** and **bsp** subdirectories.

The **bsp** subdirectory contains a variety of example BSPs. Table 15-3 lists all potential BSP examples provided in the **bsp** directory. The **bsp** directory for each hardware example only includes BSP examples supported by the associated hardware example.

**Table 15-3.** BSP Examples

Example BSP (1)	Summary
hal_reduced_footprint	Hardware abstraction layer (HAL) BSP configured to minimize memory footprint
hal_default	HAL BSP configured with all defaults
hal_zipfs	HAL BSP configured with the Altera® read-only zip file system
ucosii_net	MicroC/OS-II BSP configured with networking
ucosii_net_zipfs	MicroC/OS-II BSP configured with networking and the Altera read-only zip file system
ucosii_net_tse	MicroC/OS-II BSP configured with networking support for the Altera triple-speed Ethernet media access control (MAC)
ucosii_net_tse_zipfs	MicroC/OS-II BSP configured with networking support for the Altera triple-speed Ethernet MAC and the Altera read-only zip file system
ucosii_default	MicroC/OS-II BSP configured with all defaults

**Note to Table 15-3:**

(1) Some BSP examples might not be available on some hardware examples.

The **app** subdirectory contains a separate subdirectory for each software example supported by the hardware example, as listed in Table 15-4.

**Table 15-4.** Application Examples (1)

Application Name	Summary
Hello World	Prints 'Hello from Nios II'
Board Diagnostics	Tests peripherals on the development boards
Count Binary	Displays a running count of 0x00 to 0xff
Hello Freestanding	Prints 'Hello from Nios II' from a free-standing application
Hello MicroC/OS-II	Prints 'Hello from Nios II' using the MicroC/OS-II RTOS
Hello World Small	Prints 'Hello from Nios II' from a small footprint program
Memory Test	Runs diagnostic tests on both volatile and flash memory
Simple Socket Server	Runs a TCP/IP socket server
Web Server	Runs a web server from a file system in flash memory
Zip File System	Reads from a file system in flash memory

**Note to Table 15-4:**

(1) Some application examples might not be available on some hardware examples, depending on BSP support.

## create-this-bsp

Each BSP subdirectory contains a **create-this-bsp** script. The **create-this-bsp** script calls the **nios2-bsp** script to create a BSP in the current directory. The **create-this-bsp** script has a relative path to the directory containing the **.sopcinfo** file. The **.sopcinfo** file resides two directory levels above the directory containing the **create-this-bsp** script.

The **create-this-bsp** script takes no command-line arguments. Your current directory must be the same directory as the **create-this-bsp** script. The exit value is zero on success and one on error.

## create-this-app

Each application subdirectory contains a **create-this-app** script. The **create-this-app** script copies the C/C++ application source code to the current directory, runs **nios2-app-generate-makefile** to create a makefile (named **Makefile**), and then runs **make** to build the Executable and Linking Format File (.elf) for your application. Each **create-this-app** script uses a particular example BSP. For further information, refer to the script to determine the associated example BSP. If the BSP does not exist when **create-this-app** runs, **create-this-app** calls the associated **create-this-bsp** script to create the BSP.

The **create-this-app** script takes no command-line arguments. Your current directory must be the same directory as the **create-this-app** script. The exit value is zero on success and one on error.

## Finding create-this-app and create-this-bsp

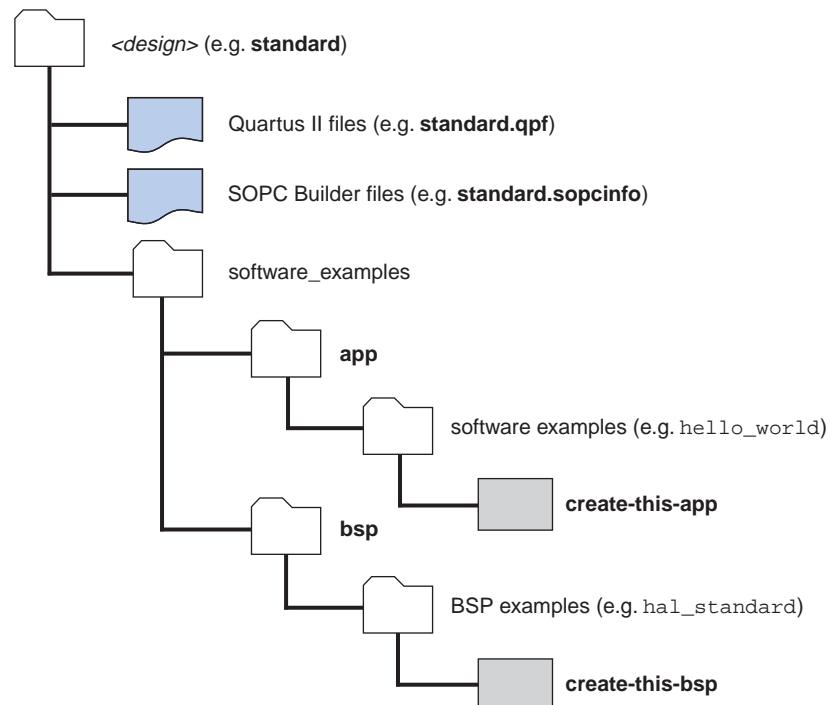
The **create-this-app** and **create-this-bsp** scripts are installed with your Nios II example designs. You can easily find them from the following information:

- Where the Nios II EDS is installed
- Which Nios development board you are using
- Which HDL you are using
- Which Nios II hardware example design you are using
- The name of the Nios II software example

The **create-this-app** script for each software example design is in `<Nios II EDS install path>/examples/<HDL>/niosII_<board type>/<design name>/software_examples/app/<example name>`. For example, the **create-this-app** script for the **Hello World** software example running on the Verilog HDL full-featured example design for the Nios II Development Kit, Cyclone® II Edition, might be located in `c:/altera/71/nios2eds/examples/verilog/niosII_cycloneII_2c35/full_featured/software_examples/app/hello_world`.

Similarly, the **create-this-bsp** script for each software example design is in `<Nios II EDS install path>/examples/<HDL>/niosII_<board type>/<design name>/software_examples/bsp/<BSP_type>`. For example, the **create-this-bsp** script for the basic HAL BSP to run on the Verilog HDL full-featured example design for the Nios II Development Kit, Cyclone II Edition, might be located in `c:/altera/71/nios2eds/examples/verilog/niosII_cycloneII_2c35/full_featured/software_examples/bsp/hal_default`.

Figure 15-1 shows the directory structure under each hardware example design.

**Figure 15-1.** Software Example Design Directory Structure

## Settings

Settings are central to how you create and work with BSPs, software packages, and device drivers. You control the characteristics of your project by controlling the settings. The settings determine things like whether or not an operating system is supported, and the device drivers and other that packages are included.

Every example in the *Getting Started from the Command Line* and *Nios II Software Build Tools* chapters of the *Nios II Software Developer's Handbook* involves specifying or manipulating settings. Sometimes these settings are specified automatically, by scripts such as **create-this-bsp**, and sometimes explicitly, with Tcl commands. Either way, settings are always involved.

This section contains a complete list of available settings for BSPs and for Altera-supported device drivers and software packages. It does not include settings for device drivers or software packages furnished by Altera partners or other third parties. If you are using a third-party driver or component, refer to the supplier's documentation.

Settings used in the Nios II Software Build Tools are organized hierarchically, for logical grouping and to avoid name conflicts. Each setting's position in the hierarchy is indicated by one or more prefixes. A prefix is an identifier followed by a dot (.). For example, `hal.enable_c_plus_plus` is a hardware abstraction layer (HAL) setting, while `ucosii.event_flag.os_flag_accept_en` is a member of the event flag subgroup of MicroC/OS-II settings.

Setting names are case-insensitive.

## Overview of BSP Settings

A BSP setting consists of a name/value pair.

The format in which you specify the setting value depends on the setting type. Several settings types are supported. Table 15-5 shows the allowed formats for each setting type.

**Table 15-5.** Setting Formats

Setting Type	Format When Setting	Format When Getting
boolean	0/1 or false/true	0/1
number	0x prefix for hexadecimal or no prefix for a decimal number	decimal
string	Quoted string Use "none" to set empty string. In the Software Build Tools command line, to specify a string value with embedded spaces, surround the string with a backslash-double-quote sequence (\"). For example: <code>--set APP_INCLUDE_DIRS \"lcd board\"</code>	Quoted string

There are several contexts for BSP settings, as shown in Table 15-6.

**Table 15-6.** BSP Setting Contexts

Setting Context	Description
Altera HAL	Settings available with the Altera HAL BSP or any BSP based on it (for example, Micrium MicroC/OS-II).
Micrium MicroC/OS-II	Settings available if using the Micrium MicroC/OS-II BSP. All Altera HAL BSP settings are also available because MicroC/OS-II is based on the Altera HAL BSP.
Altera BSP Makefile Generator	Settings available if using the Altera BSP makefile generator (generates the <b>Makefile</b> and <b>public.mk</b> files). These settings control the contents of makefile variables. This generator is always present in Altera HAL BSPs or any BSPs based on the Altera HAL.
Altera BSP Linker Script Generator	Settings available if using the Altera BSP linker script generator (generates the <b>linker.x</b> and <b>linker.h</b> files). This generator is always present in Altera HAL BSPs or any BSPs based on the Altera HAL.

Do not confuse BSP settings with BSP Tcl commands. This section covers BSP settings, including their types, meanings, and legal values. The Tcl commands, which include tools for manipulating the settings, are covered in [“Tcl Commands for BSP Settings” on page 15-68](#).

## Overview of Component and Driver Settings

The Nios II EDS includes a number of standard software packages and device drivers. All of the software packages, and several drivers, have settings that you can manipulate when creating a BSP. This section lists the packages and drivers that have settings.

You can enable a software package or driver in the Nios II BSP Editor. In the Software Build Tools command line flow, use the `enable_sw_package` Tcl command, described in [“Tcl Commands for BSP Settings” on page 15-68](#).

### Altera Host-Based File System Settings

The Altera host-based file system has one setting. If the Altera host-based file system is enabled, you must debug (not run) applications based on the BSP for the host-based file system to function. The host-based file system relies on the GNU debugger running on the host to provide host-based file operations.

The host-based file system enables debugging information in your project, by setting `APP_CFLAGS_OPTIMIZATION` to `-g` in the makefile.

To include the host-based file system in your BSP, enable the `altera_hostfs` software package.

### Altera Read-Only Zip File System Settings

The Altera read-only zip file system has several settings. If the read-only zip file system is enabled, it adds `-DUSE_RO_ZIPFS` to `ALT_CPPFLAGS` in **public.mk**.

To include the read-only zip file system in your BSP, enable the `altera_ro_zipfs` software package.

### Altera NicheStack TCP/IP - Nios II Edition Stack Settings

The Altera NicheStack® TCP/IP Network Stack - Nios II Edition has several settings. The stack is only available in MicroC/OS-II BSPs. If the NicheStack TCP/IP stack is enabled, it adds `-DALT_INICHE` to `ALT_CPPFLAGS` in **public.mk**.

To include the NicheStack TCP/IP networking stack in your BSP, enable the `altera_iniche` software package.

### Altera Avalon-MM JTAG UART Driver Settings

The Altera Avalon Memory-Mapped® (Avalon-MM) JTAG UART driver settings are available if the `altera_avalon_jtag_uart` driver is present. By default, this driver is used if your SOPC Builder system has an `altera_avalon_jtag_uart` module connected to it.

### Altera Avalon-MM UART Driver Settings

The Altera Avalon-MM UART driver settings are available if the `altera_avalon_uart` driver is present. By default, this driver is used if your SOPC Builder system has an `altera_avalon_uart` module connected to it.

## Settings Reference

This section lists all settings for BSPs, software packages, and device drivers.

**hal.enable\_instruction\_related\_exceptions\_api**

<b>Identifier</b>	none
<b>Type</b>	Boolean definition
<b>Default Value</b>	false
<b>Destination File</b>	none
<b>Description</b>	Enables application program interface (API) for registering handlers to service instruction-related exceptions. These exception types can be generated if various processor options are enabled, such as the memory management unit (MMU), memory protection unit (MPU), or other advanced exception types. Enabling this setting increases the size of the exception entry code.
<b>Restrictions</b>	none

**hal.max\_file\_descriptors**

<b>Identifier</b>	none
<b>Type</b>	Decimal number
<b>Default Value</b>	32
<b>Destination File</b>	none
<b>Description</b>	Determines the number of file descriptors statically allocated.
<b>Restrictions</b>	If hal.enable_lightweight_device_driver_api is true, there are no file descriptors so this setting is ignored. If hal.enable_lightweight_device_driver_api is false, this setting must be at least 4 because HAL needs a file descriptor for /dev/null, /dev/stdin, /dev/stdout, and /dev/stderr. This setting defines the value of ALT_MAX_FD in <b>system.h</b> .

**hal.sys\_clk\_timer**

<b>Identifier</b>	none
<b>Type</b>	Unquoted string
<b>Default Value</b>	none
<b>Destination File</b>	none
<b>Description</b>	Slave descriptor of the system clock timer device. This device provides a periodic interrupt (“tick”) and is typically required for RTOS use. This setting defines the value of ALT_SYS_CLK in <b>system.h</b> .
<b>Restrictions</b>	none

**hal.timestamp\_timer**

<b>Identifier</b>	none
<b>Type</b>	Unquoted string
<b>Default Value</b>	none
<b>Destination File</b>	none
<b>Description</b>	Slave descriptor of timestamp timer device. This device is used by Altera HAL timestamp drivers for high-resolution time measurement. This setting defines the value of ALT_TIMESTAMP_CLK in <b>system.h</b> .
<b>Restrictions</b>	none



### **ucosii.os\_max\_tasks**

<b>Identifier</b>	OS_MAX_TASKS
<b>Type</b>	Decimal number
<b>Default Value</b>	10
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Maximum number of tasks
<b>Restrictions</b>	none

### **ucosii.os\_lowest\_prio**

<b>Identifier</b>	OS_LOWEST_PRIO
<b>Type</b>	Decimal number
<b>Default Value</b>	20
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Lowest assignable priority
<b>Restrictions</b>	none

### **ucosii.os\_thread\_safe\_newlib**

<b>Identifier</b>	OS_THREAD_SAFE_NEWLIB
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Thread safe C library
<b>Restrictions</b>	none

### **ucosii.miscellaneous.os\_arg\_chk\_en**

<b>Identifier</b>	OS_ARG_CHK_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Enable argument checking
<b>Restrictions</b>	none

**ucosii.miscellaneous.os\_cpu\_hooks\_en**

<b>Identifier</b>	OS_CPU_HOOKS_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	system.h
<b>Description</b>	Enable MicroC/OS-II hooks
<b>Restrictions</b>	none

**ucosii.miscellaneous.os\_debug\_en**

<b>Identifier</b>	OS_DEBUG_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	system.h
<b>Description</b>	Enable debug variables
<b>Restrictions</b>	none

**ucosii.miscellaneous.os\_sched\_lock\_en**

<b>Identifier</b>	OS_SCHED_LOCK_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	system.h
<b>Description</b>	Include code for OSSchedLock() and OSSchedUnlock()
<b>Restrictions</b>	none

**ucosii.miscellaneous.os\_task\_stat\_en**

<b>Identifier</b>	OS_TASK_STAT_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	system.h
<b>Description</b>	Enable statistics task
<b>Restrictions</b>	none

### **ucosii.miscellaneous.os\_task\_stat\_stk\_chk\_en**

<b>Identifier</b>	OS_TASK_STAT_STK_CHK_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	system.h
<b>Description</b>	Check task stacks from statistics task
<b>Restrictions</b>	none

### **ucosii.miscellaneous.os\_tick\_step\_en**

<b>Identifier</b>	OS_TICK_STEP_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	system.h
<b>Description</b>	Enable tick stepping feature for uCOS-View
<b>Restrictions</b>	none

### **ucosii.miscellaneous.os\_event\_name\_size**

<b>Identifier</b>	OS_EVENT_NAME_SIZE
<b>Type</b>	Decimal number
<b>Default Value</b>	32
<b>Destination File</b>	system.h
<b>Description</b>	Size of name of Event Control Block groups
<b>Restrictions</b>	none

### **ucosii.miscellaneous.os\_max\_events**

<b>Identifier</b>	OS_MAX_EVENTS
<b>Type</b>	Decimal number
<b>Default Value</b>	60
<b>Destination File</b>	system.h
<b>Description</b>	Maximum number of event control blocks
<b>Restrictions</b>	none

**ucosii.miscellaneous.os\_task\_idle\_stk\_size**

<b>Identifier</b>	OS_TASK_IDLE_STK_SIZE
<b>Type</b>	Decimal number
<b>Default Value</b>	512
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Idle task stack size
<b>Restrictions</b>	none

**ucosii.miscellaneous.os\_task\_stat\_stk\_size**

<b>Identifier</b>	OS_TASK_STAT_STK_SIZE
<b>Type</b>	Decimal number
<b>Default Value</b>	512
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Statistics task stack size
<b>Restrictions</b>	none

**ucosii.task.os\_task\_change\_prio\_en**

<b>Identifier</b>	OS_TASK_CHANGE_PRIO_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Include code for OSTaskChangePrio()
<b>Restrictions</b>	none

**ucosii.task.os\_task\_create\_en**

<b>Identifier</b>	OS_TASK_CREATE_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Include code for OSTaskCreate()
<b>Restrictions</b>	none

### **ucosii.task.os\_task\_create\_ext\_en**

<b>Identifier</b>	OS_TASK_CREATE_EXT_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Include code for OSTaskCreateExt()
<b>Restrictions</b>	none

### **ucosii.task.os\_task\_del\_en**

<b>Identifier</b>	OS_TASK_DEL_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Include code for OSTaskDel()
<b>Restrictions</b>	none

### **ucosii.task.os\_task\_name\_size**

<b>Identifier</b>	OS_TASK_NAME_SIZE
<b>Type</b>	Decimal number
<b>Default Value</b>	32
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Size of task name
<b>Restrictions</b>	none

### **ucosii.task.os\_task\_profile\_en**

<b>Identifier</b>	OS_TASK_PROFILE_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Include data structure for run-time task profiling
<b>Restrictions</b>	none

**ucosii.task.os\_task\_query\_en**

<b>Identifier</b>	OS_TASK_QUERY_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	system.h
<b>Description</b>	Include code for OSTaskQuery
<b>Restrictions</b>	none

**ucosii.task.os\_task\_suspend\_en**

<b>Identifier</b>	OS_TASK_SUSPEND_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	system.h
<b>Description</b>	Include code for OSTaskSuspend() and OSTaskResume()
<b>Restrictions</b>	none

**ucosii.task.os\_task\_sw\_hook\_en**

<b>Identifier</b>	OS_TASK_SW_HOOK_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	system.h
<b>Description</b>	Include code for OSTaskSwHook()
<b>Restrictions</b>	none

**ucosii.time.os\_time\_tick\_hook\_en**

<b>Identifier</b>	OS_TIME_TICK_HOOK_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	system.h
<b>Description</b>	Include code for OSTimeTickHook()
<b>Restrictions</b>	none

### ucosii.time.os\_time\_dly\_resume\_en

<b>Identifier</b>	OS_TIME_DLY_RESUME_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	system.h
<b>Description</b>	Include code for OSTimeDlyResume()
<b>Restrictions</b>	none


### ucosii.time.os\_time\_dly\_hmsm\_en

<b>Identifier</b>	OS_TIME_DLY_HMSM_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	system.h
<b>Description</b>	Include code for OSTimeDlyHMSM()
<b>Restrictions</b>	none


### ucosii.time.os\_time\_get\_set\_en

<b>Identifier</b>	OS_TIME_GET_SET_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	system.h
<b>Description</b>	Include code for OSTimeGet and OSTimeSet()
<b>Restrictions</b>	none


### ucosii.os\_flag\_en

<b>Identifier</b>	OS_FLAG_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	system.h
<b>Description</b>	Enable code for Event Flags.  This setting is enabled by default in MicroC-OS/II BSPs, because it is required for correct functioning of Altera device drivers and the HAL in a multithreaded environment. Avoid disabling it.
<b>Restrictions</b>	none


**ucosii.event\_flag.os\_flag\_wait\_clr\_en****Identifier** OS\_FLAG\_WAIT\_CLR\_EN**Type** Boolean assignment**Default Value** 1**Destination File** system.h**Description** Include code for Wait on Clear Event Flags.

 This setting is enabled by default in MicroC-OS/II BSPs, because it is required for correct functioning of Altera device drivers and the HAL in a multithreaded environment. Avoid disabling it.


**Restrictions** none**ucosii.event\_flag.os\_flag\_accept\_en****Identifier** OS\_FLAG\_ACCEPT\_EN**Type** Boolean assignment**Default Value** 1**Destination File** system.h**Description** Include code for OSFlagAccept().

 This setting is enabled by default in MicroC-OS/II BSPs, because it is required for correct functioning of Altera device drivers and the HAL in a multithreaded environment. Avoid disabling it.

**Restrictions** none**ucosii.event\_flag.os\_flag\_del\_en****Identifier** OS\_FLAG\_DEL\_EN**Type** Boolean assignment**Default Value** 1**Destination File** system.h**Description** Include code for OSFlagDel().

 This setting is enabled by default in MicroC-OS/II BSPs, because it is required for correct functioning of Altera device drivers and the HAL in a multithreaded environment. Avoid disabling it.

**Restrictions** none**ucosii.event\_flag.os\_flag\_query\_en****Identifier** OS\_FLAG\_QUERY\_EN**Type** Boolean assignment**Default Value** 1**Destination File** system.h**Description** Include code for OSFlagQuery().

 This setting is enabled by default in MicroC-OS/II BSPs, because it is required for correct functioning of Altera device drivers and the HAL in a multithreaded environment. Avoid disabling it.

**Restrictions** none



### **ucosii.event\_flag.os\_flag\_name\_size**

<b>Identifier</b>	OS_FLAG_NAME_SIZE
<b>Type</b>	Decimal number
<b>Default Value</b>	32
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Size of name of Event Flags group. CAUTION: This is required by the HAL and many Altera device drivers; use caution in reducing this value.
<b>Restrictions</b>	none

### **ucosii.event\_flag.os\_flags\_nbits**

<b>Identifier</b>	OS_FLAGS_NBITS
<b>Type</b>	Decimal number
<b>Default Value</b>	16
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Event Flag bits (8,16,32). CAUTION: This is required by the HAL and many Altera device drivers; use caution in changing this value.
<b>Restrictions</b>	none

### **ucosii.event\_flag.os\_max\_flags**

<b>Identifier</b>	OS_MAX_FLAGS
<b>Type</b>	Decimal number
<b>Default Value</b>	20
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Maximum number of Event Flags groups. CAUTION: This is required by the HAL and many Altera device drivers; use caution in reducing this value.
<b>Restrictions</b>	none

### **ucosii.os\_mutex\_en**

<b>Identifier</b>	OS_MUTEX_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Enable code for Mutex Semaphores
<b>Restrictions</b>	none

**ucosii.mutex.os\_mutex\_accept\_en**

<b>Identifier</b>	OS_MUTEX_ACCEPT_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	system.h
<b>Description</b>	Include code for OSMutexAccept()
<b>Restrictions</b>	none


**ucosii.mutex.os\_mutex\_del\_en**

<b>Identifier</b>	OS_MUTEX_DEL_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	system.h
<b>Description</b>	Include code for OSMutexDel()
<b>Restrictions</b>	none

**ucosii.mutex.os\_mutex\_query\_en**

<b>Identifier</b>	OS_MUTEX_QUERY_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	system.h
<b>Description</b>	Include code for OSMutexQuery
<b>Restrictions</b>	none

**ucosii.os\_sem\_en**

<b>Identifier</b>	OS_SEM_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	system.h
<b>Description</b>	Enable code for semaphores.  This setting is enabled by default in MicroC-OS/II BSPs, because it is required for correct functioning of Altera device drivers and the HAL in a multithreaded environment. Avoid disabling it.
<b>Restrictions</b>	none

### ucosii.semaphore.os\_sem\_accept\_en


**Identifier** OS\_SEM\_ACCEPT\_EN

**Type** Boolean assignment

**Default Value** 1

**Destination File** system.h

**Description** Include code for OSSemAccept().

 This setting is enabled by default in MicroC-OS/II BSPs, because it is required for correct functioning of Altera device drivers and the HAL in a multithreaded environment. Avoid disabling it.

**Restrictions** none

### ucosii.semaphore.os\_sem\_set\_en

**Identifier** OS\_SEM\_SET\_EN

**Type** Boolean assignment

**Default Value** 1

**Destination File** system.h

**Description** Include code for OSSemSet().

 This setting is enabled by default in MicroC-OS/II BSPs, because it is required for correct functioning of Altera device drivers and the HAL in a multithreaded environment. Avoid disabling it.

**Restrictions** none

### ucosii.semaphore.os\_sem\_del\_en


**Identifier** OS\_SEM\_DEL\_EN

**Type** Boolean assignment

**Default Value** 1

**Destination File** system.h

**Description** Include code for OSSemDel().

 This setting is enabled by default in MicroC-OS/II BSPs, because it is required for correct functioning of Altera device drivers and the HAL in a multithreaded environment. Avoid disabling it.

**Restrictions** none

### ucosii.semaphore.os\_sem\_query\_en

**Identifier** OS\_SEM\_QUERY\_EN

**Type** Boolean assignment

**Default Value** 1

**Destination File** system.h

**Description** Include code for OSSemQuery().

 This setting is enabled by default in MicroC-OS/II BSPs, because it is required for correct functioning of Altera device drivers and the HAL in a multithreaded environment. Avoid disabling it.

**Restrictions** none

**ucosii.os\_mbox\_en**

<b>Identifier</b>	OS_MBOX_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Enable code for mailboxes
<b>Restrictions</b>	none

**ucosii.mailbox.os\_mbox\_accept\_en**

<b>Identifier</b>	OS_MBOX_ACCEPT_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Include code for OSMboxAccept()
<b>Restrictions</b>	none

**ucosii.mailbox.os\_mbox\_del\_en**

<b>Identifier</b>	OS_MBOX_DEL_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Include code for OSMboxDel()
<b>Restrictions</b>	none

**ucosii.mailbox.os\_mbox\_post\_en**

<b>Identifier</b>	OS_MBOX_POST_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Include code for OSMboxPost()
<b>Restrictions</b>	none

### **ucosii.mailbox.os\_mbox\_post\_opt\_en**

<b>Identifier</b>	OS_MBOX_POST_OPT_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Include code for OSMboxPostOpt()
<b>Restrictions</b>	none

### **ucosii.mailbox.os\_mbox\_query\_en**

<b>Identifier</b>	OS_MBOX_QUERY_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Include code for OSMboxQuery()
<b>Restrictions</b>	none

### **ucosii.os\_q\_en**

<b>Identifier</b>	OS_Q_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Enable code for Queues
<b>Restrictions</b>	none

### **ucosii.queue.os\_q\_accept\_en**

<b>Identifier</b>	OS_Q_ACCEPT_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Include code for OSQAccept()
<b>Restrictions</b>	none

**ucosii.queue.os\_q\_del\_en**

<b>Identifier</b>	OS_Q_DEL_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	system.h
<b>Description</b>	Include code for OSQDel()
<b>Restrictions</b>	none

**ucosii.queue.os\_q\_flush\_en**

<b>Identifier</b>	OS_Q_FLUSH_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	system.h
<b>Description</b>	Include code for OSQFlush()
<b>Restrictions</b>	none

**ucosii.queue.os\_q\_post\_en**

<b>Identifier</b>	OS_Q_POST_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	system.h
<b>Description</b>	Include code of OSQFlush()
<b>Restrictions</b>	none

**ucosii.queue.os\_q\_post\_front\_en**

<b>Identifier</b>	OS_Q_POST_FRONT_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	system.h
<b>Description</b>	Include code for OSQPostFront()
<b>Restrictions</b>	none

### **ucosii.queue.os\_q\_post\_opt\_en**

<b>Identifier</b>	OS_Q_POST_OPT_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Include code for OSQPostOpt()
<b>Restrictions</b>	none

### **ucosii.queue.os\_q\_query\_en**

<b>Identifier</b>	OS_Q_QUERY_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Include code for OSQQuery()
<b>Restrictions</b>	none

### **ucosii.queue.os\_max\_qs**

<b>Identifier</b>	OS_MAX_QS
<b>Type</b>	Decimal number
<b>Default Value</b>	20
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Maximum number of Queue Control Blocks
<b>Restrictions</b>	none

### **ucosii.os\_mem\_en**

<b>Identifier</b>	OS_MEM_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Enable code for memory management
<b>Restrictions</b>	none

**ucosii.memory.os\_mem\_query\_en**

<b>Identifier</b>	OS_MEM_QUERY_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	system.h
<b>Description</b>	Include code for OSMemQuery()
<b>Restrictions</b>	none

**ucosii.memory.os\_mem\_name\_size**

<b>Identifier</b>	OS_MEM_NAME_SIZE
<b>Type</b>	Decimal number
<b>Default Value</b>	32
<b>Destination File</b>	system.h
<b>Description</b>	Size of memory partition name
<b>Restrictions</b>	none

**ucosii.memory.os\_max\_mem\_part**

<b>Identifier</b>	OS_MAX_MEM_PART
<b>Type</b>	Decimal number
<b>Default Value</b>	60
<b>Destination File</b>	system.h
<b>Description</b>	Maximum number of memory partitions
<b>Restrictions</b>	none

**ucosii.os\_tmr\_en**

<b>Identifier</b>	OS_TMR_EN
<b>Type</b>	Boolean assignment
<b>Default Value</b>	0
<b>Destination File</b>	system.h
<b>Description</b>	Enable code for timers
<b>Restrictions</b>	none



### **ucosii.timer.os\_task\_tmr\_stk\_size**

<b>Identifier</b>	OS_TASK_TMR_STK_SIZE
<b>Type</b>	Decimal number
<b>Default Value</b>	512
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Stack size for timer task
<b>Restrictions</b>	none

### **ucosii.timer.os\_task\_tmr\_prio**

<b>Identifier</b>	OS_TASK_TMR_PRIO
<b>Type</b>	Decimal number
<b>Default Value</b>	2
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Priority of timer task (0=highest)
<b>Restrictions</b>	none

### **ucosii.timer.os\_tmr\_cfg\_max**

<b>Identifier</b>	OS_TMR_CFG_MAX
<b>Type</b>	Decimal number
<b>Default Value</b>	16
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Maximum number of timers
<b>Restrictions</b>	none

### **ucosii.timer.os\_tmr\_cfg\_name\_size**

<b>Identifier</b>	OS_TMR_CFG_NAME_SIZE
<b>Type</b>	Decimal number
<b>Default Value</b>	16
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Size of timer name
<b>Restrictions</b>	none

**ucosii.timer.os\_tmr\_cfg\_ticks\_per\_sec**

<b>Identifier</b>	OS_TMR_CFG_TICKS_PER_SEC
<b>Type</b>	Decimal number
<b>Default Value</b>	10
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Rate at which timer management task runs (Hz)
<b>Restrictions</b>	none

**ucosii.timer.os\_tmr\_cfg\_wheel\_size**

<b>Identifier</b>	OS_TMR_CFG_WHEEL_SIZE
<b>Type</b>	Decimal number
<b>Default Value</b>	2
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Size of timer wheel (number of spokes)
<b>Restrictions</b>	none

**altera\_avalon\_uart\_driver.enable\_small\_driver**

<b>Identifier</b>	ALTERA_AVALON_UART_SMALL
<b>Type</b>	Boolean definition
<b>Default Value</b>	false
<b>Destination File</b>	<b>public.mk</b>
<b>Description</b>	Small-footprint (polled mode) driver
<b>Restrictions</b>	none

**altera\_avalon\_uart\_driver.enable\_ioctl**

<b>Identifier</b>	ALTERA_AVALON_UART_USE_IOCTL
<b>Type</b>	Boolean definition
<b>Default Value</b>	false
<b>Destination File</b>	<b>public.mk</b>
<b>Description</b>	Enable driver ioctl() support. This feature is not compatible with the 'small' driver; ioctl() support is not compiled if either the UART 'enable_small_driver' or HAL 'enable_reduced_device_drivers' settings are enabled.
<b>Restrictions</b>	none

### **altera\_avalon\_jtag\_uart\_driver.enable\_small\_driver**

<b>Identifier</b>	ALTERA_AVALON_JTAG_UART_SMALL
<b>Type</b>	Boolean definition
<b>Default Value</b>	false
<b>Destination File</b>	<b>public.mk</b>
<b>Description</b>	Small-footprint (polled mode) driver
<b>Restrictions</b>	none

### **altera\_hostfs.hostfs\_name**

<b>Identifier</b>	ALTERA_HOSTFS_NAME
<b>Type</b>	Quoted string
<b>Default Value</b>	/mnt/host
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Mount point
<b>Restrictions</b>	none

### **altera\_iniche.iniche\_default\_if**

<b>Identifier</b>	INICHE_DEFAULT_IF
<b>Type</b>	Quoted string
<b>Default Value</b>	NOT_USED
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Deprecated setting: Default media access control (MAC) interface. This setting was formerly used by Altera networking example applications. It need not be assigned a valid value for the use of networking example designs in Nios II 8.0 or later. If you are using this setting in a project, it is recommended that you remove the dependency. This setting may be removed in a future release.
<b>Restrictions</b>	none

### **altera\_iniche.enable\_dhcp\_client**

<b>Identifier</b>	DHCP_CLIENT
<b>Type</b>	Boolean definition
<b>Default Value</b>	true
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Use dynamic host configuration protocol (DHCP) to automatically assign Internet protocol (IP) address
<b>Restrictions</b>	none

**altera\_niche.enable\_ip\_fragments**

<b>Identifier</b>	IP_FRAGMENTS
<b>Type</b>	Boolean definition
<b>Default Value</b>	true
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Reassemble IP packet fragments
<b>Restrictions</b>	none

**altera\_niche.enable\_include\_tcp**

<b>Identifier</b>	INCLUDE_TCP
<b>Type</b>	Boolean definition
<b>Default Value</b>	true
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Enable Transmission Control Protocol (TCP)
<b>Restrictions</b>	none

**altera\_niche.enable\_tcp\_zerocopy**

<b>Identifier</b>	TCP_ZEROCOPY
<b>Type</b>	Boolean definition
<b>Default Value</b>	false
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Use TCP zero-copy
<b>Restrictions</b>	none

**altera\_niche.enable\_net\_stats**

<b>Identifier</b>	NET_STATS
<b>Type</b>	Boolean definition
<b>Default Value</b>	false
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Enable statistics
<b>Restrictions</b>	none

### **altera\_ro\_zipfs.ro\_zipfs\_name**

<b>Identifier</b>	ALTERA_RO_ZIPFS_NAME
<b>Type</b>	Quoted string
<b>Default Value</b>	/mnt/rozipfs
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Mount point
<b>Restrictions</b>	none

### **altera\_ro\_zipfs.ro\_zipfs\_offset**

<b>Identifier</b>	ALTERA_RO_ZIPFS_OFFSET
<b>Type</b>	Hexadecimal number
<b>Default Value</b>	0x100000
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Offset of file system from base of flash
<b>Restrictions</b>	none

### **altera\_ro\_zipfs.ro\_zipfs\_base**

<b>Identifier</b>	ALTERA_RO_ZIPFS_BASE
<b>Type</b>	Hexadecimal number
<b>Default Value</b>	0x0
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Base address of flash memory device
<b>Restrictions</b>	none

### **hal.linker.allow\_code\_at\_reset**

<b>Identifier</b>	none
<b>Type</b>	Boolean assignment
<b>Default Value</b>	0
<b>Destination File</b>	none
<b>Description</b>	Indicates if initialization code is allowed at the reset address. If true, defines the macro ALT_ALLOW_CODE_AT_RESET in <b>linker.h</b> .
<b>Restrictions</b>	This setting is typically false if an external bootloader (e.g. flash bootloader) is present.

**hal.linker.enable\_alt\_load**

<b>Identifier</b>	none
<b>Type</b>	Boolean assignment
<b>Default Value</b>	0
<b>Destination File</b>	none
<b>Description</b>	Enables the alt_load() facility. The alt_load() facility copies sections from the .text memory into RAM. If true, this setting sets up the VMA/LMA (virtual memory address/low memory address) of sections in linker.x to allow them to be loaded into the .text memory.
<b>Restrictions</b>	This setting is typically false if an external bootloader (e.g. flash bootloader) is present.

**hal.linker.enable\_alt\_load\_copy\_exceptions**

<b>Identifier</b>	none
<b>Type</b>	Boolean assignment
<b>Default Value</b>	0
<b>Destination File</b>	none
<b>Description</b>	Causes the alt_load() facility to copy the .exceptions section. If true, this setting defines the macro ALT_LOAD_COPY_EXCEPTIONS in <b>linker.h</b> .
<b>Restrictions</b>	none

**hal.linker.enable\_alt\_load\_copy\_rodata**

<b>Identifier</b>	none
<b>Type</b>	Boolean assignment
<b>Default Value</b>	0
<b>Destination File</b>	none
<b>Description</b>	Causes the alt_load() facility to copy the .rodata section. If true, this setting defines the macro ALT_LOAD_COPY_RODATA in <b>linker.h</b> .
<b>Restrictions</b>	none

**hal.linker.enable\_alt\_load\_copy\_rwdata**

<b>Identifier</b>	none
<b>Type</b>	Boolean assignment
<b>Default Value</b>	0
<b>Destination File</b>	none
<b>Description</b>	Causes the alt_load() facility to copy the .rwdata section. If true, this setting defines the macro ALT_LOAD_COPY_RWDATA in <b>linker.h</b> .
<b>Restrictions</b>	none

### hal.linker.enable\_exception\_stack

<b>Identifier</b>	none
<b>Type</b>	Boolean assignment
<b>Default Value</b>	0
<b>Destination File</b>	none
<b>Description</b>	Enables use of a separate exception stack. If true, defines the macro ALT_EXCEPTION_STACK in <b>linker.h</b> , adds a memory region called <b>exception_stack</b> to <b>linker.x</b> , and provides the symbols <b>__alt_exception_stack_pointer</b> and <b>__alt_exception_stack_limit</b> in <b>linker.x</b> .
<b>Restrictions</b>	The <b>hal.linker.exception_stack_size</b> and <b>hal.linker.exception_stack_memory_region_name</b> settings must also be valid. This setting must be false for MicroC/OS-II BSPs. The exception stack can be used to improve interrupt and other exception performance if an EIC is not implemented.

### hal.linker.exception\_stack\_memory\_region\_name

<b>Identifier</b>	none
<b>Type</b>	Unquoted string
<b>Default Value</b>	none
<b>Destination File</b>	none
<b>Description</b>	Name of the existing memory region to be divided up to create the 'exception_stack' memory region. The selected region name is adjusted automatically when the BSP is generated to create the 'exception_stack' memory region.
<b>Restrictions</b>	Only used if <b>hal.linker.enable_exception_stack</b> is true.

### hal.linker.exception\_stack\_size

<b>Identifier</b>	none
<b>Type</b>	Decimal number
<b>Default Value</b>	1024
<b>Destination File</b>	none
<b>Description</b>	Size of the exception stack in bytes.
<b>Restrictions</b>	Only used if <b>hal.linker.enable_exception_stack</b> is true.

**hal.linker.enable\_interrupt\_stack**

<b>Identifier</b>	none
<b>Type</b>	Boolean assignment
<b>Default Value</b>	0
<b>Destination File</b>	none
<b>Description</b>	Enables use of a separate interrupt stack. If true, defines the macro <code>ALT_INTERRUPT_STACK</code> in <code>linker.h</code> , adds a memory region called <code>interrupt_stack</code> to <code>linker.x</code> , and provides the symbols <code>__alt_interrupt_stack_pointer</code> and <code>__alt_interrupt_stack_limit</code> in <code>linker.x</code> .
<b>Restrictions</b>	The <code>hal.linker.interrupt_stack_size</code> and <code>hal.linker.interrupt_stack_memory_region_name</code> settings must also be valid. This setting must be false for MicroC/OS-II BSPs. Only enable this setting for systems with an EIC. If an EIC is not implemented, use the separate exception stack to improve interrupt and other exception performance.

**hal.linker.interrupt\_stack\_memory\_region\_name**

<b>Identifier</b>	none
<b>Type</b>	Unquoted String
<b>Default Value</b>	none
<b>Destination File</b>	none
<b>Description</b>	Name of the existing memory region that is divided up to create the 'interrupt_stack' memory region. The selected region name is adjusted automatically when the BSP is generated to create the 'interrupt_stack' memory region.
<b>Restrictions</b>	Only used if <code>hal.linker.enable_interrupt_stack</code> is true.

**hal.linker.interrupt\_stack\_size**

<b>Identifier</b>	none
<b>Type</b>	Decimal Number
<b>Default Value</b>	1024
<b>Destination File</b>	none
<b>Description</b>	Size of the interrupt stack in bytes.
<b>Restrictions</b>	Only used if <code>hal.linker.enable_interrupt_stack</code> is true.

**hal.make.ar**

<b>Identifier</b>	AR
<b>Type</b>	Unquoted string
<b>Default Value</b>	nios2-elf-ar
<b>Destination File</b>	BSP makefile
<b>Description</b>	Archiver command. Creates library files.
<b>Restrictions</b>	none



### hal.make.ar\_post\_process

<b>Identifier</b>	AR_POST_PROCESS
<b>Type</b>	Unquoted string
<b>Default Value</b>	none
<b>Destination File</b>	BSP makefile
<b>Description</b>	Command executed after archiver execution.
<b>Restrictions</b>	none

### hal.make.ar\_pre\_process

<b>Identifier</b>	AR_PRE_PROCESS
<b>Type</b>	Unquoted string
<b>Default Value</b>	none
<b>Destination File</b>	BSP makefile
<b>Description</b>	Command executed before archiver execution.
<b>Restrictions</b>	none

### hal.make.as

<b>Identifier</b>	AS
<b>Type</b>	Unquoted string
<b>Default Value</b>	nios2-elf-gcc
<b>Destination File</b>	BSP makefile
<b>Description</b>	Assembler command. Note that CC is used for Nios II assembly language source files (.S).
<b>Restrictions</b>	none

### hal.make.as\_post\_process

<b>Identifier</b>	AS_POST_PROCESS
<b>Type</b>	Unquoted string
<b>Default Value</b>	none
<b>Destination File</b>	BSP makefile
<b>Description</b>	Command executed after each assembly file is compiled.
<b>Restrictions</b>	none

**hal.make.as\_pre\_process**

<b>Identifier</b>	AS_PRE_PROCESS
<b>Type</b>	Unquoted string
<b>Default Value</b>	none
<b>Destination File</b>	BSP makefile
<b>Description</b>	Command executed before each assembly file is compiled.
<b>Restrictions</b>	none

**hal.make.bsp\_arflags**

<b>Identifier</b>	BSP_ARFLAGS
<b>Type</b>	Unquoted string
<b>Default Value</b>	-src
<b>Destination File</b>	BSP makefile
<b>Description</b>	Custom flags only passed to the archiver. This content of this variable is directly passed to the archiver rather than the more standard ARFLAGS. The reason for this is that GNU Make assumes some default content in ARFLAGS. This setting defines the value of BSP_ARFLAGS in Makefile.
<b>Restrictions</b>	none

**hal.make.bsp\_asflags**

<b>Identifier</b>	BSP_ASFLAGS
<b>Type</b>	Unquoted string
<b>Default Value</b>	-Wa,-gdwarf2
<b>Destination File</b>	BSP makefile
<b>Description</b>	Custom flags only passed to the assembler. This setting defines the value of BSP_ASFLAGS in Makefile.
<b>Restrictions</b>	none

**hal.make.bsp\_cflags\_debug**

<b>Identifier</b>	BSP_CFLAGS_DEBUG
<b>Type</b>	Unquoted string
<b>Default Value</b>	-g
<b>Destination File</b>	BSP makefile
<b>Description</b>	C/C++ compiler debug level. <code>-g</code> provides the default set of debug symbols typically required to debug a typical application. Omitting <code>-g</code> removes debug symbols from the ELF. This setting defines the value of BSP_CFLAGS_DEBUG in Makefile.
<b>Restrictions</b>	none

**hal.make.bsp\_cflags\_defined\_symbols**

<b>Identifier</b>	BSP_CFLAGS_DEFINED_SYMBOLS
<b>Type</b>	Unquoted string
<b>Default Value</b>	none
<b>Destination File</b>	BSP makefile
<b>Description</b>	Preprocessor macros to define. A macro definition in this setting has the same effect as a <code>#define</code> in source code. Adding <code>-DALT_DEBUG</code> to this setting has the same effect as <code>#define ALT_DEBUG</code> in a source file. Adding <code>-DFOO=1</code> to this setting is equivalent to the macro <code>#define FOO 1</code> in a source file. Macros defined with this setting are applied to all <b>.S</b> , C source ( <b>.c</b> ), and C++ files in the BSP. This setting defines the value of <code>BSP_CFLAGS_DEFINED_SYMBOLS</code> in the BSP makefile.
<b>Restrictions</b>	none

**hal.make.bsp\_cflags\_optimization**

<b>Identifier</b>	BSP_CFLAGS_OPTIMIZATION
<b>Type</b>	Unquoted string
<b>Default Value</b>	-O0
<b>Destination File</b>	BSP makefile
<b>Description</b>	C/C++ compiler optimization level. <code>-O0</code> = no optimization, <code>-O2</code> = normal optimization, etc. <code>-O0</code> is recommended for code that you want to debug since compiler optimization can remove variables and produce nonsequential execution of code while debugging. This setting defines the value of <code>BSP_CFLAGS_OPTIMIZATION</code> in Makefile.
<b>Restrictions</b>	none

**hal.make.bsp\_cflags\_undefined\_symbols**

<b>Identifier</b>	BSP_CFLAGS_UNDEFINED_SYMBOLS
<b>Type</b>	Unquoted string
<b>Default Value</b>	none
<b>Destination File</b>	BSP makefile
<b>Description</b>	Preprocessor macros to undefine. Undefined macros are similar to defined macros, but replicate the <code>#undef</code> directive in source code. To undefine the macro <code>FOO</code> use the syntax <code>-u FOO</code> in this setting. This is equivalent to <code>#undef FOO</code> in a source file. Note: the syntax differs from macro definition (there is a space, i.e. <code>-u FOO</code> versus <code>-DFOO</code> ). Macros defined with this setting are applied to all <b>.S</b> , <b>.c</b> , and C++ files in the BSP. This setting defines the value of <code>BSP_CFLAGS_UNDEFINED_SYMBOLS</code> in the BSP Makefile.
<b>Restrictions</b>	none

**hal.make.bsp\_cflags\_user\_flags**

<b>Identifier</b>	BSP_CFLAGS_USER_FLAGS
<b>Type</b>	Unquoted string
<b>Default Value</b>	none
<b>Destination File</b>	BSP makefile
<b>Description</b>	Custom flags passed to the compiler when compiling C, C++, and <b>.S</b> files. This setting defines the value of <code>BSP_CFLAGS_USER_FLAGS</code> in Makefile.
<b>Restrictions</b>	none

**hal.make.bsp\_cflags\_warnings**

<b>Identifier</b>	BSP_CFLAGS_WARNINGS
<b>Type</b>	Unquoted string
<b>Default Value</b>	-Wall
<b>Destination File</b>	BSP makefile
<b>Description</b>	C/C++ compiler warning level. <code>-wall</code> is commonly used. This setting defines the value of BSP_CFLAGS_WARNINGS in Makefile.
<b>Restrictions</b>	none

**hal.make.bsp\_cxx\_flags**

<b>Identifier</b>	BSP_CXXFLAGS
<b>Type</b>	Unquoted string
<b>Default Value</b>	none
<b>Destination File</b>	BSP makefile
<b>Description</b>	Custom flags only passed to the C++ compiler. This setting defines the value of BSP_CXXFLAGS in Makefile.
<b>Restrictions</b>	none

**hal.make.bsp\_inc\_dirs**

<b>Identifier</b>	BSP_INC_DIRS
<b>Type</b>	Unquoted string
<b>Default Value</b>	none
<b>Destination File</b>	BSP makefile
<b>Description</b>	Space separated list of extra include directories to scan for header files. Directories are relative to the top-level BSP directory. The <code>-I</code> prefix's added by the makefile so don't add it here. This setting defines the value of BSP_INC_DIRS in Makefile.
<b>Restrictions</b>	none

**hal.make.build\_post\_process**

<b>Identifier</b>	BUILD_POST_PROCESS
<b>Type</b>	Unquoted string
<b>Default Value</b>	none
<b>Destination File</b>	BSP makefile
<b>Description</b>	Command executed after BSP built.
<b>Restrictions</b>	none

### **hal.make.build\_pre\_process**

<b>Identifier</b>	BUILD_PRE_PROCESS
<b>Type</b>	Unquoted string
<b>Default Value</b>	none
<b>Destination File</b>	BSP makefile
<b>Description</b>	Command executed before BSP built.
<b>Restrictions</b>	none

### **hal.make.cc**

<b>Identifier</b>	CC
<b>Type</b>	Unquoted string
<b>Default Value</b>	nios2-elf-gcc -xc
<b>Destination File</b>	BSP makefile
<b>Description</b>	C compiler command
<b>Restrictions</b>	none

### **hal.make.cc\_post\_process**

<b>Identifier</b>	CC_POST_PROCESS
<b>Type</b>	Unquoted string
<b>Default Value</b>	none
<b>Destination File</b>	BSP makefile
<b>Description</b>	Command executed after each <b>.c</b> or <b>.S</b> file is compiled.
<b>Restrictions</b>	none

### **hal.make.cc\_pre\_process**

<b>Identifier</b>	CC_PRE_PROCESS
<b>Type</b>	Unquoted string
<b>Default Value</b>	none
<b>Destination File</b>	BSP makefile
<b>Description</b>	Command executed before each <b>.c</b> or <b>.S</b> file is compiled.
<b>Restrictions</b>	none

**hal.make.cxx**

<b>Identifier</b>	CXX
<b>Type</b>	Unquoted string
<b>Default Value</b>	nios2-elf-gcc -xc++
<b>Destination File</b>	BSP makefile
<b>Description</b>	C++ compiler command
<b>Restrictions</b>	none

**hal.make.cxx\_post\_process**

<b>Identifier</b>	CXX_POST_PROCESS
<b>Type</b>	Unquoted string
<b>Default Value</b>	none
<b>Destination File</b>	BSP makefile
<b>Description</b>	Command executed before each C++ file is compiled.
<b>Restrictions</b>	none

**hal.make.cxx\_pre\_process**

<b>Identifier</b>	CXX_PRE_PROCESS
<b>Type</b>	Unquoted string
<b>Default Value</b>	none
<b>Destination File</b>	BSP makefile
<b>Description</b>	Command executed before each C++ file is compiled.
<b>Restrictions</b>	none

**hal.make.rm**

<b>Identifier</b>	RM
<b>Type</b>	Unquoted string
<b>Default Value</b>	rm -f
<b>Destination File</b>	BSP makefile
<b>Description</b>	Command used to remove files during 'clean' target.
<b>Restrictions</b>	none

### hal.custom\_newlib\_flags

<b>Identifier</b>	CUSTOM_NEWLIB_FLAGS
<b>Type</b>	Unquoted string
<b>Default Value</b>	none
<b>Destination File</b>	<b>public.mk</b>
<b>Description</b>	Build a custom version of newlib with the specified space-separated compiler flags.
<b>Restrictions</b>	The custom newlib build is placed in the <i>&lt;bsp root&gt;/newlib</i> directory, and is used only for applications that utilize this BSP.

### hal.enable\_c\_plus\_plus

<b>Identifier</b>	ALT_NO_C_PLUS_PLUS
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	<b>public.mk</b>
<b>Description</b>	Enable support for a subset of the C++ language. This option increases code footprint by adding support for C++ constructors. Certain features, such as multiple inheritance and exceptions are not supported. If false, adds <code>-DALT_NO_C_PLUS_PLUS</code> to <code>ALT_CPPFLAGS</code> in <b>public.mk</b> , and reduces code footprint.
<b>Restrictions</b>	none

### hal.enable\_clean\_exit

<b>Identifier</b>	ALT_NO_CLEAN_EXIT
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	<b>public.mk</b>
<b>Description</b>	When your application exits, close file descriptors, call C++ destructors, etc. Code footprint can be reduced by disabling clean exit. If disabled, adds <code>-DALT_NO_CLEAN_EXIT</code> to <code>ALT_CPPFLAGS</code> and <code>-wl,--defsym,exit=_exit</code> to <code>ALT_LDFLAGS</code> in <b>public.mk</b> .
<b>Restrictions</b>	none

### hal.enable\_exit

<b>Identifier</b>	ALT_NO_EXIT
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	<b>public.mk</b>
<b>Description</b>	Add <code>exit()</code> support. This option increases code footprint if your <code>main()</code> routine returns or calls <code>exit()</code> . If false, adds <code>-DALT_NO_EXIT</code> to <code>ALT_CPPFLAGS</code> in <b>public.mk</b> , and reduces footprint.
<b>Restrictions</b>	none

**hal.enable\_gprof**

<b>Identifier</b>	ALT_PROVIDE_GMON
<b>Type</b>	Boolean assignment
<b>Default Value</b>	0
<b>Destination File</b>	<b>public.mk</b>
<b>Description</b>	Causes code to be compiled with gprof profiling enabled and the application ELF to be linked with the GPROF library. If true, adds <code>-DALT_PROVIDE_GMON</code> to <code>ALT_CPPFLAGS</code> and <code>-pg</code> to <code>ALT_CFLAGS</code> in <b>public.mk</b> .
<b>Restrictions</b>	none

**hal.enable\_lightweight\_device\_driver\_api**

<b>Identifier</b>	ALT_USE_DIRECT_DRIVERS
<b>Type</b>	Boolean assignment
<b>Default Value</b>	0
<b>Destination File</b>	<b>public.mk</b>
<b>Description</b>	Enables lightweight device driver API. This reduces code and data footprint by removing the HAL layer that maps device names (e.g. <code>/dev/uart0</code> ) to file descriptors. Instead, driver routines are called directly. The <code>open()</code> , <code>close()</code> , and <code>lseek()</code> routines always fail if called. The <code>read()</code> , <code>write()</code> , <code>fstat()</code> , <code>ioctl()</code> , and <code>isatty()</code> routines only work for the stdio devices. If true, adds <code>-DALT_USE_DIRECT_DRIVERS</code> to <code>ALT_CPPFLAGS</code> in <b>public.mk</b> .
<b>Restrictions</b>	The Altera Host and read-only ZIP file systems can't be used if <code>hal.enable_lightweight_device_driver_api</code> is true.

**hal.enable\_mul\_div\_emulation**

<b>Identifier</b>	ALT_NO_INSTRUCTION_EMULATION
<b>Type</b>	Boolean assignment
<b>Default Value</b>	0
<b>Destination File</b>	<b>public.mk</b>
<b>Description</b>	Adds code to emulate multiply and divide instructions in case they are executed but aren't present in the processor. Normally this isn't required because the compiler won't use multiply and divide instructions that aren't present in the processor. If false, adds <code>-DALT_NO_INSTRUCTION_EMULATION</code> to <code>ALT_CPPFLAGS</code> in <b>public.mk</b> .
<b>Restrictions</b>	none

**hal.enable\_reduced\_device\_drivers**

<b>Identifier</b>	ALT_USE_SMALL_DRIVERS
<b>Type</b>	Boolean assignment
<b>Default Value</b>	0
<b>Destination File</b>	<b>public.mk</b>
<b>Description</b>	Certain drivers are compiled with reduced functionality to reduce code footprint. Not all drivers observe this setting. The <code>altera_avalon_uart</code> and <code>altera_avalon_jtag_uart</code> drivers switch from interrupt-driven to polled operation. CAUTION: Several device drivers are disabled entirely. These include the <code>altera_avalon_cfi_flash</code> , <code>altera_avalon_epcs_flash_controller</code> , and <code>altera_avalon_lcd_16207</code> drivers. This can result in certain API (HAL flash access routines) to fail. You can define a symbol provided by each driver to prevent it from being removed. If true, adds <code>-DALT_USE_SMALL_DRIVERS</code> to <code>ALT_CPPFLAGS</code> in <b>public.mk</b> .
<b>Restrictions</b>	none



### hal.enable\_runtime\_stack\_checking

<b>Identifier</b>	ALT_STACK_CHECK
<b>Type</b>	Boolean assignment
<b>Default Value</b>	0
<b>Destination File</b>	<b>public.mk</b>
<b>Description</b>	Turns on HAL runtime stack checking feature. Enabling this setting causes additional code to be placed into each subroutine call to generate an exception if a stack collision occurs with the heap or statically allocated data. If true, adds <code>-DAL_T_STACK_CHECK</code> and <code>-mstack-check</code> to <code>ALT_CPPFLAGS</code> in <b>public.mk</b> .
<b>Restrictions</b>	none

### hal.enable\_sim\_optimize

<b>Identifier</b>	ALT_SIM_OPTIMIZE
<b>Type</b>	Boolean assignment
<b>Default Value</b>	0
<b>Destination File</b>	<b>public.mk</b>
<b>Description</b>	The BSP is compiled with optimizations to speedup HDL simulation such as initializing the cache, clearing the .bss section, and skipping long delay loops. If true, adds <code>-DAL_T_SIM_OPTIMIZE</code> to <code>ALT_CPPFLAGS</code> in <b>public.mk</b> .
<b>Restrictions</b>	When this setting is true, the BSP shouldn't be used to build applications that are expected to run real hardware.

### hal.enable\_small\_c\_library

<b>Identifier</b>	none
<b>Type</b>	Boolean assignment
<b>Default Value</b>	0
<b>Destination File</b>	<b>public.mk</b>
<b>Description</b>	Causes the small newlib (C library) to be used. This reduces code and data footprint at the expense of reduced functionality. Several newlib features are removed such as floating-point support in <code>printf()</code> , stdin input routines, and buffered I/O. The small C library is not compatible with Micrium MicroC/OS-II. If true, adds <code>-msmallc</code> to <code>ALT_LDFLAGS</code> in <b>public.mk</b> .
<b>Restrictions</b>	none

### hal.enable\_sopc\_sysid\_check

<b>Identifier</b>	none
<b>Type</b>	Boolean assignment
<b>Default Value</b>	1
<b>Destination File</b>	<b>public.mk</b>
<b>Description</b>	Enable SOPC Builder System ID. If a System ID SOPC Builder component is connected to the processor associated with this BSP, it is enabled in the creation of command-line arguments to download an ELF to the target. Otherwise, system ID and timestamp values are left out of <b>public.mk</b> for the application makefile <code>download-elf</code> target definition. With the system ID check disabled, the Nios II EDS tools do not automatically ensure that the application .elf file (and BSP it is linked against) corresponds to the hardware design on the target. If false, adds <code>--accept-bad-sysid</code> to <code>SOPC_SYSID_FLAG</code> in <b>public.mk</b> .
<b>Restrictions</b>	none

**hal.log\_port**

<b>Identifier</b>	LOG_PORT
<b>Type</b>	Unquoted string
<b>Default Value</b>	none
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Slave descriptor of debug logging character-mode device. If defined, it enables extra debug messages in the HAL source. This setting is used by the ALT_LOG_PORT family of defines in <b>system.h</b> .

**hal.log\_flags**

<b>Identifier</b>	ALT_LOG_FLAGS
<b>Type</b>	Decimal Number
<b>Default Value</b>	0
<b>Destination File</b>	<b>public.mk</b>
<b>Description</b>	The value is assigned to ALT_LOG_FLAGS in the generated <b>public.mk</b> . Refer to <b>hal.log_port</b> for further details. The valid range of this setting is 1 through 4.

**hal.stderr**

<b>Identifier</b>	STDERR
<b>Type</b>	Unquoted string
<b>Default Value</b>	none
<b>Destination File</b>	<b>public.mk</b>
<b>Description</b>	Slave descriptor of STDERR character-mode device. This setting is used by the ALT_STDERR family of defines in <b>system.h</b> .

**hal.stdin**

<b>Identifier</b>	STDIN
<b>Type</b>	Unquoted string
<b>Default Value</b>	none
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Slave descriptor of STDIN character-mode device. This setting is used by the ALT_STDIN family of defines in <b>system.h</b> .

**hal.stdout**

<b>Identifier</b>	STDOUT
<b>Type</b>	Unquoted string
<b>Default Value</b>	none
<b>Destination File</b>	<b>system.h</b>
<b>Description</b>	Slave descriptor of STDOUT character-mode device. This setting is used by the ALT_STDOUT family of defines in <b>system.h</b> .

## Application and User Library Makefile Variables

The Nios II Software Build Tools construct application and makefile libraries for you, inserting makefile variables appropriate to your project configuration. You can control project build characteristics by manipulating makefile variables at the time of project generation. You control a variable with the `--set` command line option, as in the following example:

```
nios2-bsp hal my_bsp --set APP_CFLAGS_WARNINGS "-Wall" 
```

The following utilities and scripts support modifying makefile variables with the `--set` option:

- **nios2-app-generate-makefile**
- **nios2-lib-generate-makefile**
- **nios2-app-update-makefile**
- **nios2-lib-update-makefile**
- **nios2-bsp**

### Application Makefile Variables

You can modify the following application makefile variables on the command line:

- **CREATE\_OBJDUMP**—Assign 1 to this variable to enable creation of an object dump file (**.objdump**) after linking the application. The **nios2-elf-objdump** utility is called to create this file. An object dump contains information about all object files linked into the **.elf** file. It provides a complete view of all code linked into your application. An object dump contains a disassembly view showing each instruction and its address.
- **OBJDUMP\_INCLUDE\_SOURCE**—Assign 1 to this variable to include source code inline with disassembled instructions in the object dump. When enabled, this includes the `--source` switch when calling the object dump executable. This is useful for debugging and examination of how the preprocessor and compiler generate instructions from higher level source code (such as C) or from macros.
- **OBJDUMP\_FULL\_CONTENTS**—Assign 1 to this variable to include a raw display of the contents of the **.text** linker section. When enabled, this variable includes the `--full-contents` switch when calling the object dump executable.
- **CREATE\_ELF\_DERIVED\_FILES**—Setting this variable to 1 creates the HDL simulation and onchip memory initialization files when you invoke the makefile with the **all** target. When this variable is 0 (the default), these files are only created when you make the **mem-init-install** target.



Creating the HDL simulation and onchip memory initialization files increases project build time.

- **CREATE\_LINKER\_MAP**—Assign 1 to this variable to enable creation of a link map file (**.map**) after linking the application. A link map file provides information including which object files are included in the executable, the path to each object file, where objects and symbols are located in memory, and how the common symbols are allocated.

- **APP\_CFLAGS\_DEFINED\_SYMBOLS**—This variable allows you to define macros using the `-D` argument, for example `-D <macro name>`. The contents of this variable are passed to the compiler and linker without modification.
- **APP\_CFLAGS\_UNDEFINED\_SYMBOLS**—This variable allows you to remove macro definitions using the `-U` argument, for example `-U <macro name>`. The contents of this variable are passed to the compiler and linker without modification.
- **APP\_CFLAGS\_OPTIMIZATION**—The C/C++ compiler optimization level. `-O0` provides no optimization and `-O2` provides standard optimization, etc. `-O0` is recommended for debugging code, because compiler optimization can remove variables and produce non-sequential execution of code while debugging.
- **APP\_CFLAGS\_DEBUG\_LEVEL**—The C/C++ compiler debug level. `-g` provides the default set of debug symbols typically required to debug an application. Omitting `-g` omits debug symbols from the `.elf`.
- **APP\_CFLAGS\_WARNINGS**—The C/C++ compiler warning level. `-Wall` is commonly used, enabling all warning messages.
- **APP\_CFLAGS\_USER\_FLAGS**
- **APP\_INCLUDE\_DIRS**—Use this variable to specify paths for the preprocessor to search. These paths commonly contain C header files (`.h`) that application code requires. Each path name is formatted and passed to the preprocessor with the `-I` option.

You can add multiple directories by enclosing them in double quotes, for example `--set APP_INCLUDE_DIRS "../my_includes ../../other_includes"`.

- **APP\_LIBRARY\_DIRS**—Use this variable to specify paths for additional libraries that your application links with.



When you specify a user library path with **APP\_LIBRARY\_DIRS**, you also need to specify the user library names with the **APP\_LIBRARY\_NAMES** variable.


**APP\_LIBRARY\_DIRS** specifies only the directory where the user library file(s) are located, not the library archive file (`.a`) name.




Do not use this variable to specify the path to a BSP or user library created with the Software Build Tools. The paths to these libraries are specified in **public.mk** files included in the application makefile.

You can add multiple directories by enclosing them in double quotes, for example `--set APP_LIBRARY_DIRS "../my_includes ../../other_includes"`.

- **APP\_LIBRARY\_NAMES**—Use this variable to specify the names of additional libraries that your application must link with. Library files are `.a` files.

 You do not specify the full name of the **.a** file. Instead, you specify the user library name **<name>**, and the Software Build Tools construct the filename **lib<name>.a**. For example, if you add the string "math" to **APP\_LIBRARY\_NAMES**, the Software Build Tools assume that your library file is named **libmath.a**.

Each specified user library name is passed to the linker with the **-l** option. The paths to locate these libraries must be specified in the **APP\_LIBRARY\_DIRS** variable.

 You cannot use this variable to specify a BSP or user library created with the Software Build Tools. The paths to these libraries are specified in **public.mk** file included in the application makefile.

## User Library Makefile Variables

You can modify the following user library makefile variables on the command line:

- **LIB\_CFLAGS\_DEFINED\_SYMBOLS**—
- **LIB\_CFLAGS\_UNDEFINED\_SYMBOLS**—
- **LIB\_CFLAGS\_OPTIMIZATION**—The C/C++ compiler optimization level. **-O0** provides no optimization and **-O2** provides standard optimization, etc. **-O0** is recommended for debugging code, because compiler optimization can remove variables and produce non-sequential execution of code while debugging.
- **LIB\_CFLAGS\_DEBUG\_LEVEL**—The C/C++ compiler debug level. **-g** provides the default set of debug symbols typically required to debug an application. Omitting **-g** omits debug symbols from the **.elf**.
- **LIB\_CFLAGS\_WARNINGS**—The C/C++ compiler warning level. **-Wall** is commonly used, enabling all warning messages.
- **LIB\_CFLAGS\_USER\_FLAGS**—
- **LIB\_INCLUDE\_DIRS**—You can add multiple directories by enclosing them in double quotes, for example **--set LIB\_INCLUDE\_DIRS "../my\_includes ../../other\_includes"**

## Standard Build Flag Variables

The Software Build Tools create makefiles supporting the following standard makefile command-line variables:

- **CFLAGS**
- **CPPFLAGS**
- **ASFLAGS**
- **CXXFLAGS**

You can define flags in these variables on the makefile command line, or in a script that invokes the makefile. The makefile passes these flags on to the corresponding GCC tool.

## Tcl Commands

Tcl commands are a crucial component of the Nios II Software Build Tools. Tcl commands allow you to exercise detailed control over BSP generation, as well as to define drivers and software packages. This section describes the Tcl commands, the environments in which they run, and how the commands work together.

### Tcl Command Environments

The Nios II Software Build Tools support Tcl commands in the following environments:

- **BSP setting specification**—In this environment, you manipulate BSP settings to control the static characteristics of the BSP. BSP setting commands are executed before the BSP is generated.
- **BSP generation callbacks**—In this environment, you exercise further control over BSP details, managing settings that interact with one another and with the hardware design. BSP callbacks run at BSP generation time.
- **Device driver and software package definition**—In this environment, you bundle source files into a custom driver or package. This process prepares the driver or package so that a BSP developer can include it in a BSP using the Software Build Tools.

The following sections describe each Tcl environment in detail, listing the available commands.

### Tcl Commands for BSP Settings

[“Settings” on page 15-27](#) describes settings that are available in a Nios II project. This section describes the tools that you use to specify and manipulate these settings.

You manipulate project settings with BSP Tcl commands. The commands in this section are used with the utilities **nios2-bsp-create-settings**, **nios2-bsp-update-settings**, and **nios2-bsp-query-settings**. You can call the Tcl commands directly on a utility command line using the `--cmd` option, or you can put them in a Tcl script, specified with the `--script` option. For details about how to call Tcl commands from utilities, refer to [“Nios II Software Build Tools Utilities” on page 15-1](#).



For more information about creating Tcl scripts, refer to [“Tcl Scripts for BSP Settings”](#) in the *Nios II Software Build Tools* chapter of the *Nios II Software Developer's Handbook*. This chapter includes a discussion of the default Tcl script, which provides excellent usage examples of many of the Tcl commands described in this section.

The following commands are available to manipulate BSP settings:

- [“add\\_memory\\_region” on page 15-70](#)
- [“add\\_section\\_mapping” on page 15-70](#)
- [“add\\_systemh\\_line” on page 15-71](#)
- [“are\\_same\\_resource” on page 15-71](#)
- [“delete\\_memory\\_region” on page 15-72](#)

- “delete\_section\_mapping” on page 15-72
- “disable\_sw\_package” on page 15-72
- “enable\_sw\_package” on page 15-73
- “get\_addr\_span” on page 15-73
- “get\_assignment” on page 15-73
- “get\_available\_drivers” on page 15-74
- “get\_available\_sw\_packages” on page 15-74
- “get\_base\_addr” on page 15-75
- “get\_break\_offset” on page 15-75
- “get\_break\_slave\_desc” on page 15-75
- “get\_cpu\_name” on page 15-76
- “get\_current\_memory\_regions” on page 15-76
- “get\_current\_section\_mappings” on page 15-76
- “get\_default\_memory\_regions” on page 15-77
- “get\_driver” on page 15-77
- “get\_enabled\_sw\_packages” on page 15-78
- “get\_exception\_offset” on page 15-78
- “get\_exception\_slave\_desc” on page 15-79
- “get\_fast\_tlb\_miss\_exception\_offset” on page 15-79
- “get\_fast\_tlb\_miss\_exception\_slave\_desc” on page 15-79
- “get\_interrupt\_controller\_id” on page 15-80
- “get\_irq\_interrupt\_controller\_id” on page 15-80
- “get\_irq\_number” on page 15-80
- “get\_memory\_region” on page 15-80
- “get\_module\_class\_name” on page 15-81
- “get\_module\_name” on page 15-81
- “get\_reset\_offset” on page 15-82
- “get\_reset\_slave\_desc” on page 15-82
- “get\_section\_mapping” on page 15-82
- “get\_setting” on page 15-83
- “get\_setting\_desc” on page 15-83
- “get\_slave\_descs” on page 15-83
- “is\_char\_device” on page 15-84
- “iq\_connected\_interrupt\_controller\_device” on page 15-84
- “is\_connected\_to\_data\_master” on page 15-85

- “is\_connected\_to\_instruction\_master” on page 15-85
- “is\_ethernet\_mac\_device” on page 15-85
- “is\_flash” on page 15-85
- “is\_memory\_device” on page 15-86
- “is\_non\_volatile\_storage” on page 15-86
- “is\_timer\_device” on page 15-86
- “log\_debug” on page 15-87
- “log\_default” on page 15-87
- “log\_error” on page 15-87
- “log\_verbose” on page 15-87
- “set\_driver” on page 15-88
- “set\_setting” on page 15-88
- “update\_memory\_region” on page 15-88
- “update\_section\_mapping” on page 15-89

## **add\_memory\_region**

### **Usage**

`add_memory_region <name> <slave_desc> <offset> <span>`

### **Options**

- `<name>`: String with the name of the memory region to create.
- `<slave_desc>`: String with the slave descriptor of the memory device for this region.
- `<offset>`: String with the byte offset of the memory region from the memory device base address.
- `<span>`: String with the span of the memory region in bytes.

### **Description**

Creates a new memory region for the linker script. This memory region must not overlap with any other memory region and must be within the memory range of the associated slave descriptor. The offset and span are decimal numbers unless prefixed with 0x.

### **Example**

```
add_memory_region onchip_ram0 onchip_ram0 0 0x100000
```

## **add\_section\_mapping**

### **Usage**

`add_section_mapping <section_name> <memory_region_name>`



### Options

- `<section_name>`: String with the name of the linker section.
- `<memory_region_name>`: String with the name of the memory region to map.

### Description

Maps the specified linker section to the specified linker memory region. If the section does not already exist, `add_section_mapping` creates it. If it already exists, `add_section_mapping` overrides the existing mapping with the new one. The linker creates the section mappings in the order in which they appear in the linker script.

### Example

```
add_section_mapping .text onchip_ram0
```

## add\_systemh\_line

### Usage

```
add_systemh_line <sw> <name> <value>
```

- `<sw>`: The software (OS) that the **system.h** text is associated with
- `<name>`: Name of macro to write into **system.h** (left-hand side of `#define`)
- `<value>`: Name of value to assign to macro in **system.h** (right-hand side of `#define`)

### Description

Adds a line of text to the **system.h** file. The software argument should be the name of the software type (typically an operating system name) that the **system.h** text applies to. In the context of an operating system Tcl script, the name in the `create_os <name>` command must be used. The text should be a name-value pair that creates a macro (`#define` statement) in the **system.h** file.



This command may only be used by Tcl scripts that are registered to run at BSP generation time by an operating system.

### Example

```
add_systemh_line UCOSII OS_TICKS_PER_SEC 100
```

## are\_same\_resource

### Usage

```
are_same_resource <slave_desc1> <slave_desc2>
```

### Options

- `<slave_desc1>`: String with the first slave descriptor to compare.
- `<slave_desc2>`: String with the second slave descriptor to compare.

**Description**

Returns a boolean value that indicates whether the two slave descriptors are connected to the same resource. To connect to the same resource, the two slave descriptors must be associated with the same module. The module specifies whether two slaves access the same resource or different resources within that module. For example, a dual-port memory has two slaves that access the same resource (the memory). However, you could create a module that has two slaves that access two different resources such as a memory and a control port.

**delete\_memory\_region****Usage**

```
delete_memory_region <region_name>
```

**Options**

- *<region\_name>*: String with the name of the memory region to delete.

**Description**

Deletes the specified memory region. The region must exist to avoid an error condition.

**delete\_section\_mapping****Usage**

```
delete_section_mapping <section_name>
```

**Options**

- *<section\_name>*: String with the name of the section.

**Description**

Deletes the specified section mapping.

**Example**

```
delete_section_mapping .text
```

**disable\_sw\_package****Usage**

```
disable_sw_package <software_package_name>
```

**Options**

- *<software\_package\_name>*: String with the name of the software package.

**Description**

Disables the specified software package. Settings belonging to the package are no longer available in the BSP, and associated source files are not included in the BSP makefile. It is an error to disable a software package that is not enabled.

## enable\_sw\_package

### Usage

```
enable_sw_package <software_package_name>
```

### Options

- *<software\_package\_name>*: String with the name of the software package, with the version number optionally appended with a '!'.

### Description

Enables a software package. Adds its associated source files and settings to the BSP. Specify the desired version in the form *<software\_package\_name>:<version>*. If you do not specify the version, *enable\_sw\_package* selects the latest available version.

### Examples

- Example 1:

```
enable_sw_package altera_hostfs:7.2
```

- Example 2:

```
enable_sw_package my_sw_package
```

## get\_addr\_span

### Usage

```
get_addr_span <slave_desc>
```

### Options

- *<slave\_desc>*: String with the slave descriptor to query.

### Description

Returns the address span (length in bytes) of the slave descriptor as an integer decimal number.

### Example

```
puts [get_addr_span onchip_ram_64_kbytes]
```

Returns:

```
65536
```

## get\_assignment

### Usage

```
get_assignment <module_name> <assignment_name>
```

### Options

- *<module\_name>*: Module instance name to query for assignment
- *<assignment\_name>*: Module instance assignment name to query for

**Description**

Returns the name of the value of the assignment for a specified module instance name.

**Example**

```
puts [get_assignment "cpu0" "embeddedsw.configuration.breakSlave"]
```

Returns:

```
memory_0.s0
```

**get\_available\_drivers****Usage**

```
get_available_drivers <module_name>
```

**Options**

- *<module\_name>*: String with the name of the module to query.

**Description**

Returns a list of available device driver names that are compatible with the specified module instance. The list is empty if there are no drivers available for the specified slave descriptor. The format of each entry in the list is the driver name followed by a colon and the version number (if provided).

**Example**

```
puts [get_available_drivers jtag_uart]
```

Returns:

```
altera_avalon_jtag_uart_driver:7.2 altera_avalon_jtag_uart_driver:6.1
```

**get\_available\_sw\_packages****Usage**

```
get_available_sw_packages
```

**Options**

None

**Description**

Returns a list of software package names that are available for the current BSP. The format of each entry in the list is a string containing the package name followed by a colon and the version number (if provided).

**Example**

```
puts [get_available_sw_packages]
```

Returns:

```
altera_hostfs:7.2 altera_ro_zipfs:7.2
```

## **get\_base\_addr**

### **Usage**

`get_base_addr <slave_desc>`

### **Options**

- `<slave_desc>`: String with the slave descriptor to query.

### **Description**

Returns the base byte address of the slave descriptor as an integer decimal number.

### **Example**

```
puts [get_base_addr jtag_uart]
```

Returns:

```
67616
```

## **get\_break\_offset**

### **Usage**

`get_break_offset`

### **Options**

None

### **Description**

Returns the byte offset of the processor break address.

### **Example**

```
puts [get_break_offset]
```

Returns:

```
32
```

## **get\_break\_slave\_desc**

### **Usage**

`get_break_slave_desc`

### **Options**

None

### **Description**

Returns the slave descriptor associated with the processor break address. If null, then the break device is internal to the processor (debug module).;

### **Example**

```
puts [get_break_slave_desc]
```

Returns:

```
onchip_ram_64_kbytes
```

### **get\_cpu\_name**

#### **Usage**

```
get_cpu_name
```

#### **Options**

None

#### **Description**

Returns the name of the BSP specific processor.

#### **Example**

```
puts [get_cpu_name]
```

Returns:

```
cpu_0
```

### **get\_current\_memory\_regions**

#### **Usage**

```
get_current_memory_regions
```

#### **Options**

None

#### **Description**

Returns a sorted list of records representing the existing linker script memory regions. Each record in the list represents a memory region. Each record is a list containing the region name, associated memory device slave descriptor, offset, and span, in that order.

#### **Example**

```
puts [get_current_memory_regions]
```

Returns:

```
{reset onchip_ram0 0 32} {onchip_ram0 onchip_ram0 32 1048544}
```

### **get\_current\_section\_mappings**

#### **Usage**

```
get_current_section_mappings
```

#### **Options**

None

### Description

Returns a list of lists for all the current section mappings. Each list represents a section mapping with the format {section\_name memory\_region}. The order of the section mappings matches their order in the linker script.

### Example

```
puts [get_current_section_mappings]
```

Returns:

```
{.text onchip_ram0} {.rodata onchip_ram0} {.rwdata onchip_ram0}  
  {.bss onchip_ram0} {.heap onchip_ram0} {.stack onchip_ram0}
```

## get\_default\_memory\_regions

### Usage

```
get_default_memory_regions
```

### Options

None

### Description

Returns a sorted list of records representing the default linker script memory regions. The default linker script memory regions are the best guess for memory regions based on the reset address and exception address of the processor associated with the BSP, and all other processors in the system that share memories with the processor associated with the BSP. Each record in the list represents a memory region. Each record is a list containing the region name, associated memory device slave descriptor, offset, and span, in that order.

### Example

```
puts [get_default_memory_regions]
```

Returns:

```
{reset onchip_ram0 0 32} {onchip_ram0 onchip_ram0 32 1048544}
```

## get\_driver

### Usage

```
get_driver <module_name>
```

### Options

- <module\_name>: String with the name of the module instance to query.

### Description

Returns the driver name associated with the specified module instance. The format is <driver name> followed by a colon and the version (if provided). Returns the string "none" if there is no driver associated with the specified module instance name.

**Examples**

## ■ Example 1:

```
puts [get_driver jtag_uart]
```

Returns:

```
altera_avalon_jtag_uart_driver:7.2
```

## ■ Example 2:

```
puts [get_driver onchip_ram_64_kbytes]
```

Returns:

```
none
```

**get\_enabled\_sw\_packages****Usage**

```
get_enabled_sw_packages
```

**Options**

None

**Description**

Returns a list of currently enabled software packages. The format of each entry in the list is the software package name followed by a colon and the version number (if provided).

**Example**

```
puts [get_enabled_sw_packages]
```

Returns:

```
altera_hostfs:7.2
```

**get\_exception\_offset****Usage**

```
get_exception_offset
```

**Options**

None

**Description**

Returns the byte offset of the processor exception address.

**Example**

```
puts [get_exception_offset]
```

Returns:

```
32
```



## **get\_exception\_slave\_desc**

### **Usage**

`get_exception_slave_desc`

### **Options**

None

### **Description**

Returns the slave descriptor associated with the processor exception address.

### **Example**

```
puts [get_exception_slave_desc]
```

Returns:

```
onchip_ram_64_kbytes
```

## **get\_fast\_tlb\_miss\_exception\_offset**

### **Usage**

`get_fast_tlb_miss_exception_offset`

### **Options**

None

### **Description**

Returns the byte offset of the processor fast translation lookaside buffer (TLB) miss exception address. Only a processor with an MMU has such an exception address.

### **Example**

```
puts [get_fast_tlb_miss_exception_offset]
```

Returns:

```
32
```

## **get\_fast\_tlb\_miss\_exception\_slave\_desc**

### **Usage**

`get_fast_tlb_miss_exception_slave_desc`

### **Options**

None

### **Description**

Returns the slave descriptor associated with the processor fast TLB miss exception address. Only a processor with an MMU has such an exception address.

### **Example**

```
puts [get_fast_tlb_miss_exception_slave_desc]
```

Returns:

`onchip_ram_64_kbytes`

### **get\_interrupt\_controller\_id**

#### **Usage**

`get_interrupt_controller_id <slave_desc>`

#### **Options**

- `<slave_desc>`: String with the slave descriptor to query.

#### **Description**

Returns the interrupt controller ID of the slave descriptor (-1 if not a connected interrupt controller).

### **get\_irq\_interrupt\_controller\_id**

#### **Usage**

`get_irq_interrupt_controller_id <slave_desc>`

#### **Options**

- `<slave_desc>`: String with the slave descriptor to query.

#### **Description**

Returns the interrupt controller ID connected to the IRQ associated with the slave descriptor (-1 if none).

### **get\_irq\_number**

#### **Usage**

`get_irq_number <slave_desc>`

#### **Options**

- `<slave_desc>`: String with the slave descriptor to query.

#### **Description**

Returns the interrupt request number of the slave descriptor, or -1 if no interrupt request number is found.

### **get\_memory\_region**

#### **Usage**

`get_memory_region <name>`

#### **Options**

- `<name>`: String with the name of the memory region.

### Description

Returns the linker script region information for the specified region. The format of the region is a list containing the region name, associated memory device slave descriptor, offset, and span in that order.

### Example

```
puts [get_memory_region reset]
```

Returns:

```
reset onchip_ram0 0 32
```

### get\_module\_class\_name

#### Usage

```
get_module_class_name <module_name>
```

#### Options

- *<module\_name>*: String with the module instance name to query.

### Description

Returns the name of the module class associated with the module instance.

### Example

```
puts [get_module_class_name jtag_uart0]
```

Returns:

```
altera_avalon_jtag_uart
```

### get\_module\_name

#### Usage

```
get_module_name <slave_desc>
```

#### Options

- *<slave\_desc>*: String with the slave descriptor to query.

### Description

Returns the name of the module instance associated with the slave descriptor. If a module with one slave, or if it has multiple slaves connected to the same resource, the slave descriptor is the same as the module name. If a module has multiple slaves that do not connect to the same resource, the slave descriptor consists of the module name followed by an underscore and the slave name.

### Example

```
puts [get_module_name multi_jtag_uart0_s1]
```

Returns:

```
multi_jtag_uart0
```

**get\_reset\_offset****Usage**

```
get_reset_offset
```

**Options**

None

**Description**

Returns the byte offset of the processor reset address.

**Example**

```
puts [get_reset_offset]
```

Returns:

```
0
```

**get\_reset\_slave\_desc****Usage**

```
get_reset_slave_desc
```

**Options**

None

**Description**

Returns the slave descriptor associated with the processor reset address.

**Example**

```
puts [get_reset_slave_desc]
```

Returns:

```
onchip_ram_64_kbytes
```

**get\_section\_mapping****Usage**

```
get_section_mapping <section_name>
```

**Options**

- *<section\_name>*: String with the section name to query.

**Description**

Returns the name of the memory region for the specified linker section. Returns null if the linker section does not exist.

**Example**

```
puts [get_section_mapping .text]
```

Returns:

onchip\_ram0

## get\_setting

### Usage

get\_setting <name>

### Options

- <name>: String with the name of the setting to get.

### Description

Returns the value of the specified BSP setting. get\_setting returns boolean settings with the value 1 or 0. If the value of the setting is an empty string, get\_setting returns "none".

The get\_setting command is equivalent to the --get command-line option.

### Example

```
puts [get_setting hal.enable_gprof]
```

Returns:

0

## get\_setting\_desc

### Usage

get\_setting\_desc <name>

### Options

- <name>: String with the name of the setting to get the description for.

### Description

Returns a string describing the BSP setting.

### Example

```
puts [get_setting_desc hal.enable_gprof]
```

Returns:

```
"This example compiles the code with gprof profiling enabled and links \
the application ELF with the GPROF library. If true, adds \
-DALT_PROVIDE_GMON to ALT_CPPFLAGS and -pg to ALT_CFLAGS in
public.mk."
```

## get\_slave\_descs

### Usage

get\_slave\_descs

### Options

None

**Description**

Returns a sorted list of all the slave descriptors connected to the Nios II processor.

**Example**

```
puts [get_slave_descs]
```

Returns:

```
jtag_uart0 onchip_ram0
```

**is\_char\_device****Usage**

```
is_char_device <slave_desc>
```

**Options**

- <slave\_desc>: String with the slave descriptor to query.

**Description**

Returns a boolean value that indicates whether the slave descriptor is a character device.

**Examples**

- Example 1:

```
puts [is_char_device jtag_uart]
```

Returns:

```
1
```

- Example 2:

```
puts [is_char_device onchip_ram_64_kbytes]
```

Returns:

```
0
```

**iq\_connected\_interrupt\_controller\_device****Usage**

```
is_connected_interrupt_controller_device <slave_desc>
```

**Options**

- <slave\_desc>: String with the slave descriptor to query.

**Description**

Returns a boolean value that indicates whether the slave descriptor is an interrupt controller device that is connected to the processor so that the interrupt controller sends interrupts to the processor.

### **is\_connected\_to\_data\_master**

#### **Usage**

`is_connected_to_data_master <slave_desc>`

#### **Options**

- `<slave_desc>`: String with the slave descriptor to query.

#### **Description**

Returns a boolean value that indicates whether the slave descriptor is connected to a data master.

### **is\_connected\_to\_instruction\_master**

#### **Usage**

`is_connected_to_instruction_master <slave_desc>`

#### **Options**

- `<slave_desc>`: String with the slave descriptor to query.

#### **Description**

Returns a boolean value that indicates whether the slave descriptor is connected to an instruction master.

### **is\_ethernet\_mac\_device**

#### **Usage**

`is_ethernet_mac_device <slave_desc>`

#### **Options**

- `<slave_desc>`: String with the slave descriptor to query.

#### **Description**

Returns a boolean value that indicates whether the slave descriptor is an Ethernet MAC device.

### **is\_flash**

#### **Usage**

`is_flash <slave_desc>`

#### **Options**

- `<slave_desc>`: String with the slave descriptor to query.

#### **Description**

Returns a boolean value that indicates whether the slave descriptor is a flash memory device.

## is\_memory\_device

### Usage

```
is_memory_device <slave_desc>
```

### Options

- *<slave\_desc>*: String with the slave descriptor to query.

### Description

Returns a boolean value that indicates whether the slave descriptor is a memory device.

### Examples

- Example 1:

```
puts [is_memory_device jtag_uart]
```

Returns:

```
0
```

- Example 2:

```
puts [is_memory_device onchip_ram_64_kbytes]
```

Returns:

```
1
```

## is\_non\_volatile\_storage

### Usage

```
is_non_volatile_storage <slave_desc>
```

### Options

- *<slave\_desc>*: String with the slave descriptor to query.

### Description

Returns a boolean value that indicates whether the slave descriptor is a non-volatile storage device.

## is\_timer\_device

### Usage

```
is_timer_device <slave_desc>
```

### Options

- *<slave\_desc>*: String with the slave descriptor to query.

### Description

Returns a boolean value that indicates whether the slave descriptor is a timer device.



## **log\_debug**

### **Usage**

```
log_debug <message>
```

### **Options**

- *<message>*: String with message to log.

### **Description**

Displays a message to the host's stdout when the logging level is debug.

## **log\_default**

### **Usage**

```
log_default <message>
```

### **Options**

- *<message>*: String with message to log.

### **Description**

Displays a message to the host's stdout when the logging level is default or higher.

### **Example**

```
log_default "This is a default message."
```

Displays:

```
INFO: Tcl message: "This is a default message."
```

## **log\_error**

### **Usage**

```
log_error <message>
```

### **Options**

- *<message>*: String with message to log.

### **Description**

Displays a message to the host's stderr, regardless of logging level.

## **log\_verbose**

### **Usage**

```
log_verbose <message>
```

### **Options**

- *<message>*: String with message to log.

### **Description**

Displays a message to the host's stdout when the logging level is verbose or higher.

## set\_driver

### Usage

```
set_driver <driver_name> <module_name>
```

### Options

- <driver\_name>: String with the name of the device driver to use.
- <module\_name>: String with the name of the module instance to set.

### Description

Selects the specified device driver for the specified module instance. The <driver\_name> argument includes a version number, delimited by a colon (:). If you omit the version number, set\_driver uses the latest available version of the driver which is compatible with the SOPC Builder module specified by the <module\_name> argument.

If <driver\_name> is none, the specified module instance does not use a driver. If <driver\_name> is not none, it must be the name of the associated SOPC Builder module class.

### Examples

- Example 1:

```
set_driver altera_avalon_jtag_uart_driver:7.2 jtag_uart
```

- Example 2:

```
set_driver none jtag_uart
```

## set\_setting

### Usage

```
set_setting <name> <value>
```

### Options

- <name>: String with the name of the setting.
- <value>: String with the value of the setting.

### Description

Sets the value for the specified BSP setting. Legal values for boolean settings are true, false, 1, and 0. Use the keyword none instead of an empty string to set a string to an empty value. The set\_setting command is equivalent to the --set command-line option.

### Example

```
set_setting hal.enable_gprof true
```

## update\_memory\_region

### Usage

```
update_memory_region <name> <slave_desc> <offset> <span>
```

### Options

- `<name>`: String with the name of the memory region to update.
- `<slave_desc>`: String with the slave descriptor of the memory device for this region.
- `<offset>`: String with the byte offset of the memory region from the memory device base address.
- `<span>`: String with the span of the memory region in bytes.

### Description

Updates an existing memory region for the linker script. This memory region must not overlap with any other memory region and must be within the memory range of the associated slave descriptor. The offset and span are decimal numbers unless prefixed with 0x.

### Example

```
update_memory_region onchip_ram0 onchip_ram0 0 0x100000
```

## update\_section\_mapping

### Usage

```
update_section_mapping <section_name> <memory_region_name>
```

### Options

- `<section_name>`: String with the name of the linker section.
- `<memory_region_name>`: String with the name of the memory region to map.

### Description

Updates the specified linker section. The linker creates the section mappings in the order in which they appear in the linker script.

### Example

```
update_section_mapping .text onchip_ram0
```

## Tcl Commands for BSP Generation Callbacks

If you are defining a device driver or a software package, you can define Tcl callback functions to run whenever a BSP is generated containing your driver or package. Tcl callback functions enable you to create settings dynamically for the driver or package. This capability is essential when the driver or package settings must be customized to the hardware configuration, or to other BSP settings.

Tcl callback scripts are defined and controlled from the `*_sw.tcl` file associated with the driver or package. In `*_sw.tcl`, you can specify where the Tcl functions come from, when function runs, and the scope of each Tcl function's operation.

When the BSP is generated with your driver or software package, the settings you define in the callback scripts are inserted in **settings.bsp**.

You specify the source of the callback functions with the `set_sw_property` command, using the `callback_source_file` property.

A Tcl callback function can run at one of the following times:

- BSP initialization
- BSP generation
- BSP validation



Although you can specify a new setting's value when you create the setting at BSP initialization, the setting's value can change between initialization and generation. For example, the BSP developer might edit the setting in the Nios II BSP Editor.

A Tcl callback can function in either of the following scopes:

- Component class
- Component instance

You specify each callback function's runtime environment by using the appropriate property in the `set_sw_property` command, as shown in [Table 15-7](#).

**Table 15-7.** Callback Properties

Property as specified in <code>set_sw_property</code>	Run time	Scope	Callback Arguments
<code>initialization_callback</code>	Initialization	Component instance	Component instance name
<code>validation_callback</code>	Validation	Component instance	Component instance name
<code>generation_callback</code>	Generation	Component instance	Component instance name, BSP generate target directory, driver BSP subdirectory <sup>(1)</sup>
<code>class_initialization_callback</code>	Initialization	Component class	Driver class name
<code>class_validation_callback</code>	Validation	Component class	Driver class name
<code>class_generation_callback</code>	Generation	Component class	Driver class name, BSP generate target directory, driver BSP subdirectory <sup>(1)</sup>

**Note to Table 15-7:**

(1) The BSP subdirectory into which the driver or package files are copied

Tcl callbacks have access to a specialized set of commands, described in this section. In addition, Tcl callbacks can use any read-only BSP setting Tcl command.



Refer to [“Tcl Commands for BSP Settings” on page 15-68](#) for details about BSP setting Tcl commands.



When a Tcl callback creates a setting, it can specify the value. However, callbacks cannot change the value of a pre-existing setting.

### **add\_class\_sw\_setting**

#### **Usage**

```
add_class_sw_setting <setting-name> <setting-type>
```

### Options

- *<setting-name>*: Name of the setting to persist in the BSP settings file. This is prepended with the driver class name associated with this callback script
- *<setting-type>*: Type of the setting to persist in the BSP settings file.

### Description

Creates a BSP setting that is associated with a particular software driver element class. The 'set\_class\_sw\_setting\_property' command is required to set the values for fields pertaining to a BSP software setting definition. This command is only valid for a callback script. A callback script is set in the driver's \*\_sw.tcl file, using the command `set_sw_property callback_source_file <filename>`.

### Example

```
add_class_sw_setting MY_FAVORITE_SETTING String
```

## add\_class\_systemh\_line

### Usage

```
add_class_systemh_line <macro-name> <macro-value>
```

### Options

- *<macro-name>*: Macro to be added to the system.h file for the generated BSP
- *<macro-value>*: Value associated with the macro-name to be added to the system.h file for the generated BSP

### Description

This adds a system.h assignment or macro during a driver callback execution. The BSP typically uses this during the generate phase depending on the generator. This command is only valid for a callback script. A callback script is set in the driver's \*\_sw.tcl file, using the command `set_sw_property callback_source_file <filename>`.

### Example

```
add_class_systemh_line MY_MACRO "Macro_Value";
```

## add\_module\_sw\_property

### Usage

```
add_module_sw_property <property-name> <property-value>
```

### Options

- *<property-name>*: Name of the property to add to the BSP for a module instance
- *<property-value>*: Value of the property to add to the BSP for a module instance

### Description

This adds a software property to the BSP driver of this module instance. The BSP typically uses this during the generate phase depending on the generator. This command is only valid for a callback script. A callback script is set in the driver's \*\_sw.tcl file, using the command `set_sw_property callback_source_file <filename>`.

### Example

```
add_module_sw_setting MY_FAVORITE_SETTING String
```

### add\_module\_sw\_setting

#### Usage

```
add_module_sw_setting <setting-name> <setting-type>
```

#### Options

- *<setting-name>*: Name of the setting to persist in the BSP settings file. This is prepended with the module name associated with this callback script
- *<setting-type>*: Type of the setting to persist in the BSP settings file.

### Description

Creates a BSP setting that is associated with a particular instance of hardware module in a SOPC system. The 'set\_module\_sw\_setting\_property' command is required to set the values for fields pertaining to a BSP software setting definition. This command is only valid for a callback script. A callback script is set in the driver's \*\_sw.tcl file, using the command `set_sw_property callback_source_file <filename>`.

### Example

```
add_module_sw_setting MY_FAVORITE_SETTING String
```

### add\_module\_systemh\_line

#### Usage

```
add_module_systemh_line <macro-name> <macro-value>
```

#### Options

- *<macro-name>*: Macro to be added to the system.h file for the generated BSP
- *<macro-value>*: Value associated with the macro-name to be added to the system.h file for the generated BSP

### Description

This adds a system.h assignment or macro during a driver callback execution. The BSP typically uses this during the generate phase depending on the generator. This command is only valid for a callback script. A callback script is set in the driver's \*\_sw.tcl file, using the command `set_sw_property callback_source_file <filename>`.

### Example

```
add_module_systemh_line MY_MACRO "Macro_Value";
```

## get\_class\_peripheral

### Usage

```
get_class_peripheral <instance-name> <irq-number>
```

### Options

- *<instance-name>*: Name of EIC module instance to find connected peripheral for.
- *<irq-number>*: IRQ number to locate connected peripheral device

### Description

This command is used on an EIC instance callback to obtain a peripheral slave descriptor connected to a specific IRQ port number. This command is only valid for a callback script.

### Example

```
get_class_peripheral eic_1 $irq_2;
```

## get\_module\_assignment

### Usage

```
get_module_assignment <assignment-name>
```

### Options

- *<assignment-name>*: Name of the module assignment to retrieve the value for, as defined for the module instance in the **.sopcinfo** file

### Description

Given a module assignment key, return the assignment value of a module associated with the callback script using this command. The callback script must be set in the **\*\_sw.tcl** file using command 'set\_sw\_property callback\_source\_file <filename>'.

### Example

```
puts [get_module_assignment embeddedsw.configuration.isMemoryDevice]
```

Returns:

```
true
```

## get\_module\_name

### Usage

```
get_module_name
```

### Options

None

**Description**

Returns the name of the module associated with the callback script using this command. The callback script must be set in the \*\_sw.tcl file using command 'set\_sw\_property callback\_source\_file <filename>'.

**Example**

```
puts [get_module_name]
```

Returns:

```
jtag_uart
```

**get\_module\_peripheral****Usage**

```
get_module_peripheral <irq-number>
```

**Options**

- <irq-number>: IRQ number to locate connected peripheral device

**Description**

This command is used on an EIC instance callback to obtain a peripheral slave descriptor connected to a specific IRQ port number. This command is only valid for a callback script.

**Example**

```
get_module_peripheral 2;
```

**get\_module\_sw\_setting\_value****Usage**

```
get_module_sw_setting_value <setting-name>
```

**Options**

- <setting-name>: Name of the module software setting to retrieve the value for, as defined by the add\_module\_sw\_setting command.

**Description**

Given a module software setting name, return the setting value. The callback script using this command must be set in the \*\_sw.tcl file using command 'set\_sw\_property callback\_source\_file <filename>'.

You can use this command in a generation or validation callback to retrieve the current value of a setting created in an initialization callback.

**Example**

```
puts [get_module_sw_setting_value MY_SETTING]
```

Returns:

```
"My setting value"
```



## get\_peripheral\_property

### Usage

```
get_peripheral_property <slave-descriptor> <property-name>
```

### Options

- *<slave-descriptor>*: Slave descriptor of a connected peripheral device
- *<property-name>*: Property name to query from the connected peripheral device

### Description

This command is used on an EIC instance callback to obtain a connected peripheral property value. This command is only valid for a callback script. A callback script is set in the driver's \*\_sw.tcl file, using the command `set_sw_property callback_source_file <filename>`.

### Example

```
get_peripheral_property jtag_uart supports_preemption;
```

## remove\_class\_systemh\_line

### Usage

```
remove_class_systemh_line <macro-name>
```

### Options

- *<macro-name>*: Macro to be removed to the system.h file for the generated BSP

### Description

This removes a system.h assignment or macro during a driver callback execution. The BSP typically uses this during the generate phase depending on the generator. This command is only valid for a callback script. A callback script is set in the driver's \*\_sw.tcl file, using the command `set_sw_property callback_source_file <filename>`.

### Example

```
remove_class_systemh_line MY_MACRO;
```

## remove\_module\_systemh\_line

### Usage

```
remove_module_systemh_line <macro-name>
```

### Options

- *<macro-name>*: Macro to be removed to the system.h file for the generated BSP

### Description

This removes a system.h assignment or macro during a driver callback execution. The BSP typically uses this during the generate phase depending on the generator. This command is only valid for a callback script. A callback script is set in the driver's \*\_sw.tcl file, using the command `set_sw_property callback_source_file <filename>`.

### Example

```
remove_module_systemh_line MY_MACRO;
```

## set\_class\_sw\_setting\_property

### Usage

```
set_class_sw_setting_property <setting-name> <property> <value>
```

### Options

- *<setting-name>*: Name of the setting to persist in the BSP settings file associated with the driver class of this callback script
- *<property>*: Name of the setting property to update
- *<value>*: Value of the setting property to update

### Description

Update a driver class software setting property. The setting must already be added using 'add\_class\_sw\_setting' command before calling this method. This command is only valid for a callback script. A callback script is set in the driver's \*\_sw.tcl file, using the command `set_sw_property callback_source_file <filename>`.

You can set the following setting properties:

- destination
- identifier
- value
- default\_value
- description
- restrictions
- group

### Example

```
set_class_sw_setting_property MY_FAVORITE_SETTING default-value '42'
```

## set\_module\_sw\_setting\_property

### Usage

```
set_module_sw_setting_property <setting-name> <property> <value>
```

### Options

- `<setting-name>`: Name of the setting to persist in the BSP settings file associated with the SOPC module of this callback script
- `<property>`: Name of the setting property to update
- `<value>`: Value of the setting property to update

### Description

Update a module's software setting property. The setting must already be added using 'add\_module\_sw\_setting' command before calling this method. This command is only valid for a callback script. A callback script is set in the driver's \*\_sw.tcl file, using the command `set_sw_property callback_source_file <filename>`.

You can set the following setting properties:

- destination
- identifier
- value
- default\_value
- description
- restrictions
- group

### Example

```
set_module_sw_setting_property MY_FAVORITE_SETTING default-value '42'
```

## Tcl Commands for Drivers and Packages

This section describes the tools that you use to specify and manipulate the settings and characteristics of a custom software package or driver. Typically, when creating a custom software package or device driver, or importing a package or driver from another development environment, you need these more powerful tools. To manipulate settings on existing software packages and device drivers, refer to “Settings” on page 15-27 and “Tcl Commands for BSP Settings” on page 15-68.

A device driver and a software package are both collections of source files added to the BSP. A device driver is associated with a particular SOPC Builder module class (for example, `altera_avalon_jtag_uart`). A software package is not associated with any particular SOPC Builder module class, but implements a functionality such as TCP/IP.

To define a device driver or software package, you create a Tcl script defining its characteristics. This section describes the Tcl commands available to define device drivers and software packages.



For more information about creating Tcl scripts, refer to “Tcl Scripts for BSP Settings” in the *Nios II Software Build Tools* chapter of the *Nios II Software Developer's Handbook*.

The following commands are available for device driver and software package creation:

- “add\_sw\_property” on page 15-98
- “add\_sw\_setting” on page 15-100
- “create\_driver” on page 15-102
- “create\_os” on page 15-103
- “create\_sw\_package” on page 15-103
- “set\_sw\_property” on page 15-104

## add\_sw\_property

### Usage

`add_sw_property <property> <value>`

### Options

- `<property>`: Name of property.
- `<value>`: Value assigned, or appended to the current value.

### Description

This command defines a property for a device driver or software package. A property is a list of values (for example, a list of file names). The `add_sw_property` command defines a property if it is not already defined. The command appends a new value to the list of values if the property is already defined.

In the case of a property consisting of a file name or directory name, use a relative path. Specify the path relative to the directory containing the Tcl script.

This command supports the following properties:

- `asm_source`—Adds a Nios II assembly language source file (`.s` or `.S`) to BSPs containing your package. **nios2-bsp-generate-files** copies assembly source files into a BSP and adds them to the source build list in the BSP makefile. This property is optional.
- `c_source`—Adds a C source file (`.c`) to BSPs containing your package. **nios2-bsp-generate-files** copies C source files into a BSP and adds them to the source build list in the BSP makefile. This property is optional.
- `cpp_source`—Adds a C++ source file (`.cpp`, `.cc`, or `.cxx`) to BSPs containing your package. **nios2-bsp-generate-files** copies the C++ source files into a BSP and adds them to the source build list in the BSP makefile. This property is optional.
- `include_source`—Adds an include file (typically `.h`) to BSPs containing your package. **nios2-bsp-generate-files** copies include files into a BSP, but does not add them to the generated makefile. This property is optional.

- **include\_directory**—Adds a directory to the ALT\_INCLUDE\_DIRS variable in the BSP's **public.mk** file. Adding a directory to ALT\_INCLUDE\_DIRS allows all source files to find include files in this directory. **add\_sw\_property** adds the path to the generated public makefile shared by the BSP and applications or libraries referencing it. **add\_sw\_property** compiles all files with the include directory listed in the compiler arguments.  
This property is optional.
- **lib\_source**—Adds a precompiled library file (typically .a) to each BSP containing the driver or package. **nios2-bsp-generate-files** copies the precompiled library file into the BSP directory and adds both the library file name and the path (required to locate the library file) into the BSP's **public.mk** file. Applications using the BSP link with the library file.  
The library file name must conform to the following pattern:  
**lib<name>.a**  
where <name> is a nonempty string.  
Example:  
`add_sw_property lib_source HAL/lib/libcomponent.a`  
This property is optional.
- **specific\_compatible\_hw\_version**—Specifies that the device driver only supports the specified SOPC Builder module hardware version. See the **version** property of the **set\_sw\_property** command for information about version strings. This property applies only to device drivers (see the **create\_driver** command), not to software packages. If your driver supports all versions of a peripheral after a specific release, use the **set\_property min\_compatible\_hw\_version** command instead. This property is optional.  
This property is only available for device drivers.
- **supported\_bsp\_type**—Adds a specific BSP type (operating system) to the list of supported operating systems that the driver or software package supports. Specify HAL if the software supports the Altera HAL, or operating systems that extend it. If your software is operating system-neutral and works on multiple HAL-based operating systems, state HAL only. If your software or driver contains code that depends on a particular operating system, state compatibility with that operating system only, but not HAL.  
The name of another operating system to support must match the name of the operating system exactly. This operating system name string is the same as that used to create a BSP with the **nios2-bsp-\*** commands, as well as in the .tcl script that describes the operating system, in its **create\_os** command.  
When a user creates a BSP with an operating system that extends HAL, such as UCOSII and the BSP tools select a driver for a particular hardware module, precedence is given to drivers which state compatibility with a that specific operating system (OS) before a more generic driver stating HAL compatibility. This property is only available for device drivers and software packages. This property must be set to at least one BSP (operating system) type.
- **alt\_cppflags\_addition**—Adds a line of arbitrary text to the ALT\_CPPFLAGS variable in the BSP **public.mk** file. This technique can be useful if you wish to have a static compilation flag or definition that all BSP, application, and library files receive during software build. This property is optional.

- `excluded_hal_source`—Specifies a file to exclude from the a BSP generated with an operating system that extends HAL. This property is only valid for operating systems, created with the `create_os` command. The value should be the path to a BSP file to exclude, with respect to the BSP root. This property is optional.
- `systemh_generation_script`—Specifies a `.tcl` script to execute during generation of the BSP `system.h` file. This script runs with the tcl commands available to other BSP settings tcl scripts, and allow you to influence the contents of the `system.h` file. This property is available only to operating systems, created with the `create_os` command. This property is optional.

## add\_sw\_setting

### Usage

```
add_sw_setting <type> <destination> <displayName>
               <identifier> <value> <description>
```

### Options

- `<type>`: Setting type - Boolean, QuotedString, UnquotedString.
- `<destination>`: The destination BSP file associated with the setting, or the module generator that processes this setting.
- `<displayName>`: Setting name.
- `<identifier>`: Name of the macro created for a generated destination file.
- `<value>`: Default value of the setting.
- `<description>`: Setting description.

### Description

This command creates a BSP setting associated with a software package or device driver. The setting is available whenever the software package or device driver is present in the BSP. **nios2-bsp-generate-files** converts the setting and its value into either a C preprocessor macro or BSP makefile variable. `add_sw_setting` passes macro definitions to the compiler using the `-D` command-line option, or adds them to the `system.h` file as `#define` statements.

The setting only exists once even if there are multiple instances of a software package. Set or get the setting with the `--set` and `--get` command-line options of the **nios2-bsp**, **nios2-bsp-create-settings**, **nios2-bsp-query-settings**, and **nios2-bsp-update-settings** commands. You can also use the BSP Tcl commands `set_setting` and `get_setting` to set or get the setting. The value of the setting persists in the BSP settings file.

To create a setting, you must define each of the following parameters:

- **type**—This parameter formats the setting value during BSP generation. The following supported types and usage restrictions apply:
  - **boolean\_define\_only**—Defines a macro if the setting's value is 1 or true. Example: `#define LCD_PRESENT`. No macro is defined if the setting's value is 0 or false. This setting type supports the `system_h_define` and `public_mk_define` generators.
  - **boolean**—Defines a macro or makefile variable to 1 (if the value is 1 or true) or 0 (if the value is 0 or false). Example: `#define LCD_PRESENT 1`. This type supports all generators.
  - **character**—Defines a macro with a single character with single quotes around the character. Example: `#define DELIMITER ':'`. This type supports the `system_h_define` destination.
  - **decimal\_number**—Decimal numbers define a macro or makefile variable with an unquoted decimal (integer) number. Example: `#define NUM_COPROCESSORS 3`. This type supports all destinations.
  - **double**—Double numbers have a macro name and setting value in the destination file including decimal point. Example: `#define PI 3.1416`. This type supports the `system_h_define` destination.
  - **float**—Float numbers have a macro name and setting value in the destination file including decimal point and 'f' character. Example: `#define PI 3.1416f`. This type supports the `system_h_define` destination.
  - **hex\_number**—Hex numbers have a macro name and setting value in the destination file with 0x prepended to the value. Example: `#define LCD_SIZE 0x1000`. This type supports the `system_h_define` destination.
  - **quoted\_string**—Quoted strings always have the macro name and setting value added to the destination files. In the destination, the setting value is enclosed in quotation marks. Example:  
`#define DFLT_ERR "General error"`  
 If the setting value contains white space, you must also place quotation marks around the value string in the Tcl script.  
 This type supports the `system_h_define` destination.
  - **unquoted\_string**—Unquoted strings define a macro or makefile variable with setting name and value in the destination file. In the destination file, the setting value is not enclosed in quotation marks. Example:  
`#define DFLT_ERROR Error`  
 This type supports all destinations.

- **destination**—The destination parameter specifies where `add_sw_setting` puts the setting in the generated BSP. `add_sw_settings` supports the following destinations:
  - **system\_h\_define**—With this destination, `add_sw_settings` formats settings as `#define <setting name> [<setting value>]` macros in the **system.h** file
  - **public\_mk\_define**—With this destination, `add_sw_settings` formats settings as `-D<setting name>[=<setting value>]` additions to the `ALT_CPPFLAGS` variable in the BSP **public.mk** file. **public.mk** passes the flag to the C preprocessor for each source file in the BSP, and in applications and libraries using the BSP.
  - **makefile\_variable**—With this destination, `add_sw_settings` formats settings as makefile variable additions to the BSP makefile. The variable name must be unique in the makefile.
- **displayName**—The name of the setting. Settings exist in a hierarchical namespace. A period separates levels of the hierarchy. Settings created in your Tcl script are located in the hierarchy under the driver or software package name you specified in the `create_driver` or `create_sw_package` command. Example: `my_driver.my_setting`. The Nios II Software Build Tools add the hierarchical prefix to the setting name.
- **identifier**—The name of the macro or makefile variable being defined. In a setting added to the **system.h** file at generation time, this parameter corresponds to the text immediately following the `#define` statement.
- **value**—The default value associated with the setting. If the user does not assign a value to the option, its value is this default value. Valid initial values are `true`, `1`, `false`, and `0` for `boolean` and `boolean_define_only` setting types, a single character for the `character` type, integer numbers for the `decimal_number` setting type, integer numbers with or without a `0x` prefix for the `hex_number` type, numbers with decimals for `float_number` and `double_number` types, or an arbitrary string of text for quoted and unquoted string setting types. For string types, if the value contains any white space, you must enclose it in quotation marks.
- **description**—Descriptive text that is inserted along with the setting value and name in the **summary.html** file. You must enclose the description in quotation marks if it contains any spaces. If the description includes any special characters (such as quotation marks), you must escape them with the backslash (`\`) character. The description field is mandatory, but can be an empty string (`" "`).

## create\_driver

### Usage

```
create_driver <name>
```

### Options

- **<name>**: Name of device driver.



### Description

This command creates a new device driver instance available for the Nios II Software Build Tools. This command must precede all others that describe the device driver in its Tcl script. You can only have one `create_driver` command in each Tcl script. If the `create_driver` command appears in the Tcl script, the `create_sw_package` and `create_os` commands cannot appear.

The name argument is usually distinct from all other device drivers and software packages that the Software Build Tools might locate. You can specify driver name identical to another driver if the driver you are describing has a unique version number assignment.

If your driver differs for different BSP (OS) types, you need to provide a unique name for each BSP type.

This command is required, unless you use the `create_sw_package` or `create_os` commands, as appropriate.

### **create\_os**

#### Usage

```
create_os <name>
```

#### Options

- `<name>`: Name of operating system (BSP type).

### Description

This command creates a new operating system (OS) instance (also known as a BSP type) available for the Nios II BSP tools. This command must precede all others that describe the OS in its Tcl script. You can only have one `create_os` command in each Tcl script. If the `create_os` command appears in the Tcl script, the `create_driver` or `create_sw_package` commands cannot appear.

The name argument is usually distinct from all other operating systems that the Software Build Tools might locate. You can specify an OS name identical to OS if the OS you are describing has a unique version number assignment.

This command is required, unless you use the `create_driver` or `create_sw_package` commands, as appropriate.

### **create\_sw\_package**

#### Usage

```
create_sw_package <name>
```

#### Options

- `<name>`: Name of the software package.

### Description

This command creates a new software package instance available for the Nios II Software Build Tools. This command must precede all others that describe the software package in its Tcl script. You can only have one `create_sw_package` command in each Tcl script. If the `create_sw_package` command appears in the Tcl script, the `create_driver` or `create_os` commands cannot appear.

The name argument is usually distinct from all other device drivers and software packages that the Software Build Tools might locate. You can specify a name identical to another software package if the software package you are describing has a unique version number assignment.

If your software package differs for different BSP (OS) types, you need to provide a unique name for each BSP type.

This command is required, unless you use the `create_driver` or `create_os` commands, as appropriate.

### set\_sw\_property

#### Usage

```
set_sw_property <property> <value>
```


#### Options

- `<property>`: Type of software property being set.
- `<value>`: Value assigned to the property.

### Description

Sets the specified value to the specified property. The properties this command supports can only hold a single value. This command overwrites the existing (or default) contents of a particular property with the specified value. This command applies to device drivers and software packages.

This command supports the following properties:

- `hw_class_name`—The name of the hardware class which your device driver supports. The hardware class name is also the Component Name shown in SOPC Builder Component Editor. Example: `altera_avalon_uart`. This property is only available for device drivers.  
 If your driver supports a user-defined component created with SOPC Builder 7.0 or earlier, you must append `_classic` to the class name. If you create (or update) your component with the SOPC Builder 7.1 (or later) component editor, there is no need to append `_classic`. This property is required for all drivers.
- `version`—The version number of this package. `set_sw_property` uses version numbers to determine compatibility between hardware (peripherals) and their software (drivers), as well as to choose the most recent software or driver if multiple compatible versions are available. A version can be any alphanumeric string, but is usually a major and one or more minor revision integers. The dot (.) character separates major and minor revision numbers. Examples: `9.0`, `5.0sp1`, `3.2.11`. This property is optional, but recommended. If you do not specify a version, the newest version of the package is used.

- **min\_compatible\_hw\_version**—Specifies that the device driver supports the specified hardware version, or all greater versions. This property is only available for device drivers. If your device driver supports only one or more specific versions of a hardware class, use the **add\_sw\_property specific\_compatible\_hw\_version** command instead. See the **version** property documentation for information about version strings. This property is optional. This property is only available for device drivers.
- **auto\_initialize**—Boolean value that specifies **alt\_sys\_init.c** needs to initialize your package. If enabled, you must provide a header file containing **INSTANCE** and **INIT** macros per the instructions in the *Nios II Software Developer's Handbook*. This property is optional; if unspecified, **alt\_sys\_init.c** does not contain references to your driver or software. This property is only available for device drivers and software packages.
- **bsp\_subdirectory**—Specifies the top-level directory where **nios2-bsp-generate-files** copies all source files for this package. This property is a path relative to the top-level BSP directory. This property is optional; if unspecified, **nios2-bsp-generate-files** copies the driver or software package into the **drivers** subdirectory of any BSP including this software.
- **alt\_sys\_init\_priority**—This property assigns a priority to the software package or device driver. The value of this property must be a positive integer. Use this property to customize the order of macro calls in the BSP **alt\_sys\_init.c** file. Specifying the priority is useful if your software or driver must be initialized before or after other software in the system. For example, your driver might depend on another driver already being initialized. This property is optional. The default priority is 1000. This property is only available for device drivers and software packages.
- **display\_name**—This property is used for user interfaces and other tools that wish to show a human-readable name to identify the software being described in the **.tcl** script. The **display\_name** should be set to a few words of text (in quotes) that name your software. For example: Altera Nios II driver. This property is optional. If not set, tools that attempt to use the display name use the package name created with the appropriate **create\_** command.
- **extends\_bsp\_type**—This property specifies which BSP type that an operating system (created with the **create\_os** command) extends (if any). Currently, only the Altera HAL (HAL) is supported. This command is required for all operating systems that wish to use HAL-compatible generators in the Nios II BSP tools. It is also required for operating systems that require the Altera HAL, device driver, or software package source files that are HAL compatible in BSPs created with that operating system. An operating system that extends HAL is presumed to be compatible with device drivers that support HAL. This command is only available for operating systems.
- **callback\_source\_file**—This property specifies a Tcl source file containing callback functions.

- `initialization_callback`—This property specifies the name of a Tcl callback function which is intended to run in the following environment:
  - Run time: initialization
  - Scope: component instance
  - Function argument(s): component instance name
- `validation_callback`—This property specifies the name of a Tcl callback function which is intended to run in the following environment:
  - Run time: validation
  - Scope: component instance
  - Function argument(s): component instance name
- `generation_callback`—This property specifies the name of a callback function which is intended to run in the following environment:
  - Run time: generation
  - Scope: component instance
  - Function argument(s): component instance name, BSP generate target directory, driver BSP subdirectory
- `class_initialization_callback`—This property specifies the name of a callback function which is intended to run in the following environment:
  - Run time: initialization
  - Scope: component instance
  - Function argument(s): driver class name
- `class_validation_callback`—This property specifies the name of a callback function which is intended to run in the following environment:
  - Run time: validation
  - Scope: component instance
  - Function argument(s): driver class name
- `class_generation_callback`—This property specifies the name of a callback function which is intended to run in the following environment:
  - Run time: generation
  - Scope: component instance
  - Function argument(s): driver class name, BSP generate target directory, driver BSP subdirectory

## Path Names

There are some restrictions on how you can specify file paths when working with the Nios II Software Build Tools. The tools are designed for the maximum possible compatibility with a variety of computing environments. By following the restrictions in this section, you can ensure that the build tools work smoothly with other tools in your tool chain.

## Command Arguments

Many Nios II software build tool commands take file name and directory path arguments. You can provide these arguments in any of several supported cross-platform formats. The Nios II Software Build Tools support the following path name formats:

- **Quoted Windows**—A drive letter followed by a colon, followed by directory names delimited with backslashes, surrounded by double quotes. Example of a quoted Windows absolute path:

```
"c:\altera\72\nios2eds\examples\verilog\niosII_cyclone_1c20\standard"
```

Quoted Windows relative paths omit the drive letter, and begin with two periods followed by a backslash. Example:

```
"..\niosII_cyclone_1c20\standard"
```

- **Escaped Windows**—The same as quoted Windows, except that each backslash is replaced by a double backslash, and the double quotes are omitted. Examples:

```
c:\\altera\\72\\nios2eds\\examples\\verilog\\niosII_cyclone_1c20\\standard
..\niosII_cyclone_1c20\\standard
```

- **Linux**—An optional forward slash, followed by directory names delimited with forward slashes. Examples:

```
/altera/72/nios2eds/examples/verilog/niosII_cyclone_1c20/standard
verilog/niosII_cyclone_1c20/standard
```

Linux relative paths begin with two periods followed by a forward slash.

Example:

```
../niosII_cyclone_1c20/standard
```

- **Mixed**—The same as quoted Windows, except that each backslash is replaced by a forward slash, and the double quotes are omitted. Examples:

```
c:/altera/72/nios2eds/examples/verilog/niosII_cyclone_1c20/standard
../niosII_cyclone_1c20/standard
```

- **Cygwin**—An absolute Cygwin path consists of the pseudo-directory name "/cygdrive/", followed by the lower case Windows drive name, followed by directory names delimited with forward slashes. Example:

```
/cygdrive/c/altera/72/nios2eds/examples/verilog/niosII_cyclone_1c20/standard
```

Cygwin relative paths are the same as Linux relative paths. Example:

```
../niosII_cyclone_1c20/standard
```

The Nios II Software Build Tools accept both relative and absolute path names.

Table 15-8 shows the supported path name formats for each platform, for Nios II Software Build Tools utilities and makefiles.

**Table 15-8.** Path Name Format Support

Context	Formats supported on Linux (1)	Formats supported on Windows with Cygwin
Utilities and scripts	Linux	<ul style="list-style-type: none"> <li>■ Quoted Windows (2)</li> <li>■ Mixed (2)</li> <li>■ Escaped Windows (2)</li> <li>■ Cygwin</li> </ul>
Makefiles	Linux	<ul style="list-style-type: none"> <li>■ Mixed (3)</li> <li>■ Cygwin (3)</li> </ul>
<b>Notes to Table 15-8:</b> (1) These rules apply to any Unix-like platform. (2) These rules apply to other Unix-like shells running on Windows. The Nios II Command Shell, provided with the Nios II EDS, is based on Cygwin. Examples in this chapter are designed for the Nios II Command Shell. (3) The build tools automatically convert path names to Cygwin format		

## Object File Directory Tree

The makefile created by the Nios II Software Build Tools creates a new directory tree for generated object files. To the extent possible, the object file directory tree retains the structure of the corresponding source directory.

For example, if you specify the path to a source file as

```
src/util/special/tools.c
```

the makefile places the corresponding object code in

```
obj/util/special/tools.o
```



The object file directory structure is illustrated in “Nios II Software Projects” in the *Nios II Software Build Tools* chapter of the *Nios II Software Developer’s Handbook*.

The makefile does not create object directories outside the project directory root. If the source file path you specify is a relative path beginning with “.”, the Nios II Software Build Tools “flatten” the path name prior to creating the object directory structure.

For example, if you specify the path to a source file as

```
../special/tools.c
```

the makefile places the corresponding object code in

```
obj/tools.o
```

If you specify an absolute path to source files under Cygwin, the Nios II Software Build Tools create the obj directory structure as if you had used the Cygwin form of the path name. For example, if you specify the path to a source file as

```
c:/dev/app/special/tools.c
```

the Nios II Software Build Tools place the corresponding object code in

```
obj/cygdrive/c/dev/app/special/tools.o
```

## Referenced Documents

This chapter references the following documents:

- *Getting Started from the Command Line* chapter of the *Nios II Software Developer's Handbook*
- *Nios II Software Build Tools* chapter of the *Nios II Software Developer's Handbook*

## Document Revision History

Table 15-9 shows the revision history for this document.

**Table 15-9.** Document Revision History (Part 1 of 2)

Date & Document Version	Changes Made	Summary of Changes
November 2009 v9.1.0	<ul style="list-style-type: none"> <li>■ Add documentation for the following utilities: <ul style="list-style-type: none"> <li>■ <b>nios2-lib-update-makefile</b></li> <li>■ <b>nios2-app-update-makefile</b></li> <li>■ <b>nios2-convert-ide2sbt</b></li> <li>■ <b>nios2-example-sw-create</b></li> <li>■ <b>nios2-elf-insert</b></li> <li>■ <b>nios2-elf-query</b></li> <li>■ <b>nios2-flash-programmer</b></li> </ul> </li> <li>■ Add documentation for <code>--jdi</code> command-line argument</li> <li>■ Add documentation for example design scripts</li> <li>■ Add documentation for <b>hal.log_flags</b> setting</li> <li>■ Add documentation for interrupt stack settings</li> <li>■ Clarify information about default settings for MicroC/OS-II</li> <li>■ Clarify information about default settings for host file system</li> <li>■ Add documentation for makefile variables</li> <li>■ Add documentation for the following BSP Tcl commands: <ul style="list-style-type: none"> <li>■ <code>add_systemh_line</code></li> <li>■ <code>get_assignment</code></li> <li>■ <code>get_cpu_name</code></li> <li>■ <code>get_interrupt_controller_id</code></li> <li>■ <code>get_irq_interrupt_controller_id</code></li> <li>■ <code>is_connected_interrupt_controller_device</code></li> </ul> </li> <li>■ Describe Tcl callback functions</li> </ul>	<ul style="list-style-type: none"> <li>■ New utilities <ul style="list-style-type: none"> <li>■ <b>nios2-lib-update-makefile</b></li> <li>■ <b>nios2-flash-programmer-generate</b></li> </ul> </li> <li>■ Support for external interrupt controller</li> <li>■ Support for separate interrupt stack</li> <li>■ Tcl callback functions for device drivers and software packages</li> </ul>
March 2009 v9.0.0	<ul style="list-style-type: none"> <li>■ Reorganized and updated information and terminology to clarify role of Nios II Software Build Tools.</li> <li>■ Described usage of custom Tcl scripts</li> <li>■ Corrected minor typographical errors.</li> </ul>	Custom Tcl scripts

**Table 15-9.** Document Revision History (Part 2 of 2)

<b>Date &amp; Document Version</b>	<b>Changes Made</b>	<b>Summary of Changes</b>
May 2008 v8.0.0	Describe new BSP setting <code>hal.enable_instruction_related_exceptions_api</code> .	<ul style="list-style-type: none"><li>■ Advanced exceptions added to Nios II core</li><li>■ Instruction-related exception handling added to HAL</li></ul>
October 2007 v7.2.0	Initial release. Reference material moved here from former <i>Nios II Software Build Tools</i> chapter.	—



## Introduction

This chapter familiarizes you with the main features of the Nios® II integrated development environment (IDE).



In most cases, you should create new projects using either the Nios II Software Build Tools for Eclipse™ or the Software Build Tools command line. The IDE will be discontinued in a future release. IDE support is for the following situations:

- Working with pre-existing Nios II IDE software projects
- Creating new projects for the Nios II C2H compiler
- Debugging with the FS2 console



If your hardware design was created with SOPC Builder 7.0 or earlier, you must either use the Nios II IDE development flow, or update your hardware design.

This chapter contains the following sections:

- “Differences from the Nios II Software Build Tools”
- “Getting Started with the Nios II IDE” on page A-4
- “Developing Software with the Nios II IDE” on page A-7
- “Porting Nios II IDE Projects to the Software Build Tools” on page A-18
- “Archiving Nios II IDE Software Projects” on page A-21
- “Help System” on page A-22



For more information on all topics related to the Nios II IDE, refer to the Nios II IDE help system.

## The Nios II IDE Tools

Table A-1 describes the tools provided by the Nios II IDE user interface.

## Differences from the Nios II Software Build Tools

The Nios II EDS offers two software development tool flows, as described in “Nios II Software Development Environment” in the *Overview* chapter of the *Nios II Software Developer’s Handbook*. The Nios II IDE is the key part of the Nios II IDE development flow. This section describes some importance differences between the Software Build Tools development flow and the Nios II IDE development flow.

**Table A-1.** The Nios II IDE and Associated Tools

Tools	Description
The Nios II IDE	The Nios II IDE is a software development user interface for the Nios II processor. All software development tasks can be accomplished in the IDE, including editing, building, and debugging programs. For more information, refer to the Nios II IDE help system.
Flash programmer	<p>The Nios II IDE includes a flash programmer utility that allows you to program flash memory chips on a target board. The flash programmer supports programming flash on any board, including Altera development boards and your own custom boards. The flash programmer facilitates programming flash for the following purposes:</p> <ul style="list-style-type: none"> <li>■ Executable code and data</li> <li>■ Bootstrap code to copy code from flash to RAM, and then run from RAM</li> <li>■ Hardware Abstraction Layer (HAL) file subsystems</li> <li>■ FPGA hardware configuration data</li> </ul> <p>For more information, refer to the <i>Nios II Flash Programmer User Guide</i>.</p>
Instruction set simulator	Altera provides an instruction set simulator (ISS) for the Nios II processor. The ISS is available in the Nios II Studio, and the process for running and debugging programs on the ISS is the same as for running and debugging on target hardware. For more information, refer to the Nios II Studio help system.
Quartus® II Programmer	The Quartus II programmer is part of the Altera Complete Design Suite, however the Nios II IDE can start the Quartus II programmer directly. The Quartus II programmer allows you to download new FPGA configuration files to the board. For more information, refer to the Nios II IDE help system, or to the Quartus II help system.

## Nios II IDE Makefiles

A major difference between the Nios II IDE software development flow and the Nios II Software Build Tools flow is the difference in makefile implementation. The Nios II Software Build Tools generate user-managed makefiles that you can read, and modify in detail using the Software Build Tools. In the Nios II IDE development flow, the IDE creates and manages your project makefiles for you.

The key differences between user-managed makefiles and Nios II IDE makefiles are as follows:

- The Nios II IDE has control over the contents of a makefile in an IDE project.
- In a Nios II IDE makefile, the structure and syntax are optimized for automation rather than for human readability.
- It is not normally necessary or recommended for you to read or modify a Nios II IDE makefile.

## Nios II IDE Terminology

The Nios II Software Build Tools and the Nios II IDE are described with somewhat different project terminology. Where the meaning is unambiguous, this handbook uses the Software Build Tools terminology for both development flows. The IDE terminology is used where needed to distinguish the Nios II IDE development flow from the Software Build Tools development flow.

The terminology differences are listed in [Table A-2](#).

**Table A-2.** Nios II IDE Terminology

Nios II IDE Terminology	Software Build Tools Terminology
Nios II C/C++ application	Nios II application
Nios II C/C++ library	Nios II user library
System library	Board support package (BSP)
System library option	BSP setting
Software component	Software package

## Altera Nios II Instruction Set Simulator

The Nios II ISS allows you to begin developing programs before the target hardware platform is ready. The Nios II IDE allows you to run programs on the ISS as easily as running on a real hardware target.

## Command-Line Tools

Although the Nios II IDE is primarily a graphical user interface (GUI), it includes some commands for use at the Nios II Command Shell. This section describes those commands.

### Nios II IDE Command-Line Tools

Table A-3 shows the command-line utilities that form the basis of the Nios II IDE. These tools can create and build Nios II IDE projects without launching the Nios II IDE GUI. However, Altera recommends that you use the Nios II Software Build Tools to address command-line needs, as well as for all new projects.



For detailed information about the Nios II Software Build Tools, refer to the *Nios II Software Build Tools* chapter of the *Nios II Software Developer's Handbook*.

Each of the Nios II IDE command-line tools launches the Nios II IDE in the background, without displaying the GUI. You cannot use these utilities while the IDE is running, because only one instance of the Nios II IDE can be active at a time.

The Nios II IDE command-line tools are in the `<Nios II EDS install path>/bin/` directory.

**Table A-3.** Nios II IDE Command-Line Tools

Tool	Description
<code>nios2-create-system-library</code>	Creates a new system library project.
<code>nios2-create-application-project</code>	Creates a new C/C++ application project.
<code>nios2-build-project</code>	Builds a project using the Nios II IDE managed-make facilities. Creates or updates the makefiles to build the project, and optionally runs make. <code>nios2-build-project</code> operates only on projects that exist in the current Nios II IDE workspace.
<code>nios2-import-project</code>	Imports a previously-created Nios II IDE project into the current workspace.
<code>nios2-delete-project</code>	Removes a project from the Nios II IDE workspace, and optionally deletes files from the file system.



The Nios II IDE command-line tools must be supplied with a workspace location. This location is supplied by means of the `-data <path to workspace>` command-line argument. The path to the workspace must not contain whitespace. Otherwise, any valid disk location can be used for the workspace. The workspace shown in [Example A-1](#) is the default workspace which is used by the IDE.

---

**Example A-1.** Specifying a Workspace on the Command Line

---

```
nios2-create-project \  
-data c:/altera/80/nios2eds/bin/eclipse/nios2-ide-workspace-8.0 \  
<other arguments>
```

---

**FS2 Command-Line Interface**

The `nios2-console` command opens the FS2 command-line interface, connects to the Nios II processor, and optionally downloads code.



The FS2 console is not compatible with the Nios II Software Build Tools for Eclipse.

## Getting Started with the Nios II IDE

This section describes the key components of the Nios II IDE, and describes how to create and debug a software project.

### The Nios II IDE Workbench

The term “workbench” refers to the desktop development environment for the Nios II IDE. The workbench is where you edit, compile and debug your programs in the IDE.

**Perspectives, Editors, and Views**

Each workbench window contains one or more perspectives. Each perspective provides a set of capabilities for accomplishing a specific type of task.

Most perspectives in the workbench comprise an editor area and one or more views. An editor allows you to open and edit a project resource (i.e., a file, folder, or project). Views support editors, provide alternative presentations, and ways to navigate the information in your workbench.

Any number of editors can be open at once, but only one can be active at a time. The main menu bar and toolbar for the workbench window contain operations that are applicable to the active editor. Tabs in the editor area indicate the names of resources that are currently open for editing. An asterisk (\*) indicates that an editor has unsaved changes. Views can also provide their own menus and toolbars, which, if present, appear along the top edge of the view. To open the menu for a view, click the drop-down arrow icon at the right of the view's toolbar or right-click in the view. A view might appear on its own, or stacked with other views in a tabbed notebook.

### EDS Development Flows and the Nios II IDE

The Nios II IDE can be used with both Nios II Embedded Design Suite (EDS) development flows. The main distinction between the two development flows is in the management of the project.

## Nios II IDE Projects and Makefiles

In the Nios II IDE development flow, the IDE manages Nios II C/C++ application and board support package (BSP) projects and makefiles that you create with the **New Project** wizard in Nios II IDE. The best way to modify and build an IDE project is through the IDE. You manage the BSP project settings with the **System Library** page of the **Properties** dialog box.



In the Nios II IDE, the term “system library” is used for a BSP project.

## Software Build Tools Projects and Makefiles

In the Nios II Software Build Tools development flow, you manage Nios II application, user library, and BSP projects and makefiles, giving you total control. Typically, you create Software Build Tools projects outside of the Nios II IDE and then import them into the IDE for debugging.



Software build tools projects and Nios II IDE projects are not interchangeable. However, you can manually convert an IDE project to a Software Build Tools project.



For details, refer to “[Porting Nios II IDE Projects to the Software Build Tools](#)” on [page A-18](#).

## Creating a New Nios II IDE-Managed Project

The Nios II IDE provides a **New Project** wizard that guides you through the steps to create new IDE projects. To start the **New Project** wizard for Nios II C/C++ application projects, on the File menu in the Nios II C/C++ perspective, point to **New**, and then click **Nios II C/C++ Application**.

The Nios II C/C++ application **New Project** wizard prompts you to specify:

1. A name for your new Nios II project.
2. The target hardware.
3. A template for the new project.

Project templates are ready-made, working software projects that serve as examples to show you how to structure your own Nios II projects. It is often easier to start with a working “Hello World” project, than to start a blank project from scratch.

When the Nios II IDE creates the new application project, it also creates a BSP project. If the name of the application project is *<name>*, the default name of the BSP project is *<name>\*\_syslib* (for example, *dhystone\_0\_syslib*). These projects appear in the Nios II C/C++ Projects view of the workbench.



The first time you create or build a Nios II project, the Nios II IDE automatically creates a project in your workspace called **altera.components**. This project contains links to the source code files for all Altera-provided device drivers and software packages, enabling you to step through system code in the debugger, set breakpoints, and use other debugger features. The **altera.components** project appears in the Nios II C/C++ Projects view. The Nios II C/C++ view protects the source files in **altera.components** from accidental deletion, because they are shared among all software projects. Do not attempt to circumvent this protection.

## Building and Managing Projects

Right-clicking on any resource (a file, folder, or project) opens a context-sensitive menu containing commands that you can perform on the resource. Right-clicking is usually the quickest way to find the command you need, though commands are also available in menus and toolbars.

To compile a Nios II project, right-click the project in the Nios II C/C++ Projects view, and click **Build Project**. When building, the Nios II IDE first builds the BSP project (and any other project dependencies), and then compiles the main project. Any warnings or errors are displayed in the Tasks view.

Right-clicking a project in the Nios II C/C++ Projects view also allows you to access the following important options for managing the project:

- **Properties**—Manage the dependencies on target hardware and other projects
- **System Library Properties**—Manage hardware-specific settings, such as communication devices and memory partitioning
- **Build Project**—i.e., make
- **Run As**—Run the program on hardware or under simulation
- **Debug As**—Debug the program on hardware or under simulation

### Debug and Release Configurations

You can select a Debug or Release configuration in the **Project Properties** dialog box, under **C/C++ Build**. The project configuration controls the optimization level and debug compiler options.

## Running and Debugging Programs

Run and debug operations are available by right-clicking the Nios II project. The Nios II IDE allows you to run or debug the project either on a target board, under the Nios II ISS, or under the ModelSim® logic simulator. For example, to run the program on a target board, right-click the project in the Nios II C/C++ Projects view, point to **Run As**, and then click **Nios II Hardware**. Character I/O to `stdout` and `stderr` are displayed in the Console view.

Starting a debug session is similar to starting a run session. For example, to debug the program on the ISS, right-click the project in the Nios II C/C++ Projects view, point to **Debug As**, and then click **Nios II Instruction Set Simulator**.

Launching the debugger changes the workbench perspective to the debug perspective. You can easily switch between the debug perspective and the Nios II C/C++ development perspective by clicking on the **Open Perspective** icon at the upper right corner of the workbench window.

After you start a debug session, the debugger loads the program, sets a breakpoint at `main()`, and begins executing the program. You use the usual controls to step through the code: Step Into, Step Over, Resume, Terminate, etc. To set a breakpoint, double click in the left-hand margin of the code view, or right-click in the margin and then click **Add Breakpoint**.

The Nios II IDE offers many views that allow you to examine the status of the processor while debugging, such as the Variables, Expressions, Registers, and Memory views.

## Programming Flash

Many Nios II processor systems use external flash memory to store one or more of the following items:

- Program code
- Program data
- FPGA configuration data
- File systems

The Nios II IDE provides a Flash Programmer utility to help you manage and program the contents of flash memory.



To program a Software Build Tools C/C++ application to flash memory, you must first specify an SOPC Builder System File, as follows:

1. Click **Browse** at the right of the **SOPC Builder System PTF File** box.
2. Locate the SOPC Builder System File on which the application's BSP is based. For example, if you are using a Nios II Software Build Tools example, the SOPC Builder System File is three levels up in the directory tree from the software project.

## Developing Software with the Nios II IDE

In many ways, Nios II software development with the Nios II IDE is the same as development with the Software Build Tools. The processor architecture, Hardware Abstraction Layer (HAL), software packages and drivers are the same. However, there are a few limitations and differences in tool flow details. This section discusses those differences and limitations.

### Using the HAL in an IDE Project

Like the Nios II Software Build Tools development flow, the Nios II IDE flow can automatically keep your system library up to date with the SOPC Builder system. In an IDE project, the Nios II IDE manages the system library and updates the driver configurations to accurately reflect the system hardware. If the SOPC Builder system changes — i.e., the SOPC Builder system file (**.ptf**) is updated — the IDE rebuilds the system library the next time you build or run your C/C++ application program.

#### Generated Files

The Nios II IDE development flow uses different file name and directory structure conventions for some generated system library files, as described in this section.

##### **generated.x**

In a Nios II IDE project, the **generated.x** file is the same as the **linker.x** file created by the Nios II build tools.



**generated.gdb**

In a Nios II IDE project, the **generated.gdb** file is the same as the **memory.gdb** file created by the Nios II build tools.

**alt\_main.c**

In a Nios II IDE project, you can find **alt\_main.c** in *<Nios II EDS install path>/components/altera\_hal/HAL/src*.

**System Library Settings**

In a Nios II IDE project, you manage the system library project settings with the **System Library** page of the **Properties** dialog box.



For details of how to control system library settings, refer to the Nios II IDE help system.

**Reducing Code Footprint**

The basic techniques for reducing code footprint are the same in the Nios II IDE flow as in the Software Build Tools flow, but you use a different procedure to specify the system library options. You control the following system library options through the Nios II IDE system properties dialog box:

**Table A-4.** System Library Options for Reducing Code Footprint

Technique	System Library Option Name
Use Reduced Device Drivers	<b>Reduced device drivers</b>
Reduce the File Descriptor Pool	<b>Max file descriptors</b>
Use a Smaller File I/O Library	<b>Small C library</b>
Use the Lightweight Device Driver API	<b>Lightweight device driver API</b>
Eliminate Clean Exit	<b>Clean exit (flush buffers)</b>
Eliminate All Exit Code	<b>Program never exits</b>
Turn off C++ Support	<b>Support C++</b>

**Paths to Hardware Abstraction Layer Files**

In Nios II IDE projects, HAL source files are in several directories. You can find HAL-related files in the following locations:

- The *<Nios II EDS install path>/components* directory contains most HAL source files.
- *<Nios II EDS install path>/components/altera\_hal/HAL/inc/sys* contains header files defining the HAL generic device models. In a `#include` directive, reference these files relative to *<Nios II EDS install path>/components/altera\_hal/HAL/inc/*. For example, to include the direct memory access (DMA) drivers, use `#include sys/alt_dma.h`
- *<Nios II EDS install path>/bin* contains the newlib ANSI C library header files.
- The Quartus II Complete Design Suite includes HAL drivers for SOPC Builder components distributed with the Quartus II Complete Design Suite. For example, if the design suite is installed in `c:\altera\80`, you can find the drivers under `c:\altera\80\ip\sopc_builder_ip`.



## Overriding HAL Functions

In the Nios II IDE build flow, you can override any HAL source file, including **alt\_sys\_init.c**, by placing your own implementation in your system project directory. When building the executable, the Nios II IDE finds your function, and uses it in place of the HAL version.

## Device Drivers for Nios II IDE Projects

HAL device drivers work the same in the Nios II IDE flow as in the Software Build Tools flow. However, there are slight differences in how you create a device driver.

Compared with the Nios II IDE, Nios II Software Build Tools provide a less rigid set of file naming and location requirements for your drivers. However, Altera recommends using the Nios II IDE conventions to maintain build-flow compatibility. Provided you use the file hierarchy described in “Integrating a Device Driver in the HAL” in the *Developing Device Drivers for the Hardware Abstraction Layer* chapter of the *Nios II Software Developer’s Handbook*, your device driver is compatible with the Nios II IDE development flow.

This section describes how to develop device drivers for Nios II IDE projects.

### Integrating a Device Driver in the HAL

This section discusses how to take advantage of the HAL’s ability to instantiate and register device drivers during system initialization. You can take advantage of this service, whether you created a device driver for one of the HAL generic device models, or you created a peripheral-specific device driver. Taking advantage of the automation provided by the HAL is mainly a process of placing files in the appropriate place in the HAL directory structure.

### Device Driver Files for the HAL

This section describes how to provide appropriate files to integrate your device driver into the HAL.

- **A Device’s HAL Header File and alt\_sys\_init.c**—At the heart of the HAL is the autogenerated source file, **alt\_sys\_init.c**. **alt\_sys\_init.c** contains the source code that the HAL uses to initialize the device drivers for all supported devices in the system. In particular, this file defines the `alt_sys_init()` function, which is called before `main()` to initialize all devices and make them available to the program.




Refer to “Creating a Custom Device Driver for the HAL” in the *Developing Device Drivers for the Hardware Abstraction Layer* chapter of the *Nios II Software Developer’s Handbook* for more information about **alt\_sys\_init.c**.

- **A Device's HAL Header File and alt\_sys\_init.c**—In the Nios II IDE development flow, for each device visible to the processor, the generator utility searches for an associated header file in the device's HAL/inc directory. The name of the header file depends on the SOPC Builder component name. For example, for Altera's JTAG UART component, the generator finds the file **altera\_avalon\_jtag\_uart/HAL/inc/altera\_avalon\_jtag\_uart.h**. If the generator utility finds such a header file, it inserts code into alt\_sys\_init.c to perform the following actions:
  - Include the device's header file.
  - Call the macro `<name of device>_INSTANCE` to allocate storage for the device.
  - Call the macro `<name of device>_INIT` inside the `alt_sys_init()` function to initialize the device.
- **Device Driver Source Code**—Place any required source code in the **HAL/src** directory. In addition, you should include a makefile fragment, **component.mk**. The **component.mk** file lists the source files to include in the system library. You can list multiple files by separating filenames with a space. [Example A-2](#) shows an example makefile fragment for Altera's JTAG UART device.

The Nios II IDE includes the **component.mk** file into the top-level makefile when compiling system library projects and application projects. **component.mk** can only modify the make variables listed in [Table A-5](#).

**component.mk** can add additional make rules and macros as required, but interoperability macro names should conform to the namespace rules.

 For details about namespace rules, refer to "Namespace Allocation" in the *Developing Device Drivers for the Hardware Abstraction Layer* chapter of the *Nios II Software Developer's Handbook*.

#### Example A-2. component.mk for a UART Driver

```
C_LIB_SRCS += altera_avalon_uart.c
ASM_LIB_SRCS +=
INCLUDE_PATH +=
```

**Table A-5.** Make Variables Defined in component.mk

Make Variable	Meaning
C_LIB_SRCS	The list of C source files to build into the system library.
ASM_LIB_SRCS	The list of assembler source files to build into the system library (these are preprocessed with the C preprocessor).
INCLUDE_PATH	A list of directories to add to the include search path. The directory <code>&lt;component&gt;/HAL/inc</code> is added automatically and so does not need to be explicitly defined by the component.

## Overriding the Default Device Drivers

The Nios II IDE locates all include and source files using search paths. The system library project directory is always searched first. If you place an alternative driver in the system library project directory, it overrides drivers installed with the Nios II EDS. For example, if a component provides the header file `alt_my_component.h`, and the system library project directory also contains a file `alt_my_component.h`, the version provided in the system library project directory is used at compile time. This same mechanism can override C and assembler source files.

## Exception Handling in a Nios II IDE Project

Exception handling with the internal interrupt controller in Nios II IDE projects is largely the same as in Software Build Tools projects. This section discusses the differences.



The Nios II IDE development flow does not support external interrupt controllers.

### Software Trap Handling

If your software is compiled for release, the exception handler makes a distinction between traps and other exceptions. If your software is compiled for debug, traps and other exceptions are handled identically, by executing a `break` instruction.



For more information about HAL software exception handling, refer to “HAL Exception Handling System Implementation” in the *Exception Handling* chapter of the *Nios II Software Developer’s Handbook*.



The instruction-related exception handler is unavailable in Nios II IDE projects.

### Advanced Exceptions

Advanced exception support, including the instruction-related exception handler, is not available in the Nios II IDE development flow.

### Using the Unimplemented Instruction Handler

To include the unimplemented instruction handler in a Nios II IDE project, turn on **Emulate multiply and divide instructions** on the **System properties** page of the Nios II IDE.



You do not normally need the unimplemented instruction handler, because the HAL includes software emulation for unimplemented instructions from its run-time libraries if you are compiling for a Nios II processor that does not support the instructions.

For further information about the unimplemented instruction handler, refer to “HAL Exception Handling System Implementation” in the *Exception Handling* chapter of the *Nios II Software Developer’s Handbook*.

## Configuring MicroC/OS-II Projects with the Nios II IDE

In the Nios II IDE, the displayed MicroC/OS-II setting names are different from the equivalent BSP setting names. This section lists the meanings of the IDE setting names.

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*.

### MicroC/OS-II General Options

Table A-6 shows the general MicroC/OS-II options available through the Nios II IDE.

**Table A-6.** General Options

Option	Description
<b>Maximum number of tasks</b>	Specifies the value of the <code>OS_MAX_TASKS</code> preprocessor symbol. Must be at least 2
<b>Lowest assignable priority</b>	Specifies the value of the <code>OS_LOWEST_PRIO</code> preprocessor symbol. Maximum allowable value is 63.
<b>Thread safe C library</b>	Enable thread-safe C library
<b>Enable code for event flags</b>	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 “ <a href="#">Event Flag Settings</a> ” on page A-13.
<b>Enable code for mutex semaphores</b>	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 “ <a href="#">Mutex Settings</a> ” on page A-13
<b>Enable code for semaphores</b>	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 “ <a href="#">Semaphore Settings</a> ” on page A-13.
<b>Enable code for mailboxes</b>	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 “ <a href="#">Mailbox Settings</a> ” on page A-14.
<b>Enable code for queues</b>	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 “ <a href="#">Queue Settings</a> ” on page A-14.
<b>Enable code for memory management</b>	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 “ <a href="#">Memory Management Settings</a> ” on page A-15.
<b>Enable code for timers</b>	Enable code for timers

## Event Flag Settings

Table A-7 shows the event flag settings available through the Nios II IDE.

**Table A-7.** 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 <code>OSFlagAccept()</code>	Specifies the value of the <code>OS_FLAG_ACCEPT_EN</code> preprocessor symbol.
Include code for <code>OSFlagDel()</code>	Specifies the value of the <code>OS_FLAG_DEL_EN</code> preprocessor symbol.
Include code for <code>OSFlagQuery()</code>	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 A-8 shows the mutex settings available through the Nios II IDE.

**Table A-8.** Mutex Settings

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

## Semaphore Settings

Table A-9 shows the semaphore settings available through the Nios II IDE.

**Table A-9.** Semaphores Settings

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

## Mailbox Settings

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

**Table A-10.** Mailboxes Settings

Setting	Description
<b>Include code for OSMboxAccept()</b>	Specifies the value of the OS_MBOX_ACCEPT_EN preprocessor symbol.
<b>Include code for OSMBoxDel()</b>	Specifies the value of the OS_MBOX_DEL_EN preprocessor symbol.
<b>Include code for OSMboxPost()</b>	Specifies the value of the OS_MBOX_POST_EN preprocessor symbol.
<b>Include code for OSMboxPostOpt()</b>	Specifies the value of the OS_MBOX_POST_OPT_EN preprocessor symbol.
<b>Include code for OSMBoxQuery()</b>	Specifies the value of the OS_MBOX_QUERY_EN preprocessor symbol.

## Queue Settings

Table A-11 shows the queue settings available through the Nios II IDE.

**Table A-11.** Queues Settings

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

## Memory Management Settings

Table A-12 shows the memory management settings available through the Nios II IDE.

**Table A-12.** Memory Management Settings

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

## Miscellaneous Settings

Table A-13 shows the miscellaneous settings available through the Nios II IDE.

**Table A-13.** Miscellaneous Settings

Setting	Description
<b>Enable argument checking</b>	Specifies the value of the <code>OS_ARG_CHK_EN</code> preprocessor symbol.
<b>Enable uCOS-II hooks</b>	Specifies the value of the <code>OS_CPU_HOOKS_EN</code> preprocessor symbol.
<b>Enable debug variables</b>	Specifies the value of the <code>OS_DEBUG_EN</code> preprocessor symbol.
<b>Include code for OSSchedLock() and OSSchedUnlock()</b>	Specifies the value of the <code>OS_SCHED_LOCK_EN</code> preprocessor symbol.
<b>Enable tick stepping feature for uCOS-View</b>	Specifies the value of the <code>OS_TICK_STEP_EN</code> preprocessor symbol.
<b>Enable statistics task</b>	Specifies the value of the <code>OS_TASK_STAT_EN</code> preprocessor symbol.
<b>Check task stacks from statistics task</b>	Specifies the value of the <code>OS_TASK_STAT_STK_CHK_EN</code> preprocessor symbol.
<b>Statistics task stack size</b>	Specifies the value of the <code>OS_TASK_STAT_STK_SIZE</code> preprocessor symbol.
<b>Idle task stack size</b>	Specifies the value of the <code>OS_TASK_IDLE_STK_SIZE</code> preprocessor symbol.
<b>Maximum number of event control blocks</b>	Specifies the value of the <code>OS_MAX_EVENTS</code> preprocessor symbol.
<b>Size of semaphore, mutex, mailbox, or queue name</b>	Specifies the value of the <code>OS_EVENT_NAME_SIZE</code> preprocessor symbol.

## Task Management Settings

Table A-14 shows the task management settings available through the Nios II IDE.

**Table A-14.** Task Management Settings

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

## Time Management Settings

Table A-15 shows the time management settings available through the Nios II IDE.

**Table A-15.** Time Management Settings

Setting	Description
Include code for OStimeDlyHMSM()	Specifies the value of the OS_TIME_DLY_HMSM_EN preprocessor symbol.
Include code for OStimeDlyResume()	Specifies the value of the OS_TIME_DLY_RESUME_EN preprocessor symbol.
Include code for OStimeGet() and OStimeSet()	Specifies the value of the OS_TIME_GET_SET_EN preprocessor symbol.
Include code for OStimeTickHook()	Specifies the value of the OS_TIME_TICK_HOOK_EN preprocessor symbol.



## Timer Management Settings

Table A-16 shows the timer management settings available through the Nios II IDE.

**Table A-16.** Timer Management Settings

Setting	Description
Maximum number of timers	Specifies the maximum number of timers
Determine the size of a timer name	Specifies 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

## Using NicheStack in a Nios II IDE Project

This section discusses the details of how to use the NicheStack TCP/IP Stack in the Nios II IDE.

### get\_mac\_addr() and get\_ip\_addr()

The NicheStack TCP/IP Stack system code calls `get_mac_addr()` and `get_ip_addr()` during the device initialization process. These functions are necessary for the system code to set the media access control (MAC) and IP addresses for the network interface, which you select through **MAC interface** in the **NicheStack TCP/IP Stack** tab of the **Software Components** dialog box.

`INICHE_DEFAULT_IF`, defined in **system.h**, identifies the network interface that you defined in SOPC Builder. In the Nios II IDE, you can set `INICHE_DEFAULT_IF` through the **MAC interface** control in the **NicheStack TCP/IP Stack** tab of the **Software Components** dialog box.

`DHCP_CLIENT`, also defined in **system.h**, specifies whether to use the dynamic host configuration protocol (DHCP) client application to obtain an IP address. You can set or clear this setting in the Nios II IDE (with the **Use DHCP to automatically assign IP address** check box)

### Configuring the NicheStack TCP/IP Stack in the Nios II IDE

The Nios II IDE allows you to configure certain options (i.e. modify the `#defines` in **system.h**) without editing source code. The most commonly accessed options are available through the **NicheStack TCP/IP Stack** tab of the **Software Components** dialog box.



If you modify the **ipport.h** file directly, be careful not to select the **Clean Project** build option in the Nios II IDE. Selecting **Clean Project** results in your modified **ipport.h** file being replaced with the starting template version of this file.

## Porting Nios II IDE Projects to the Software Build Tools

The Nios II Software Build Tools use a different directory structure and settings file format than the Nios II IDE. Therefore, if you wish to take advantage of the Nios II Software Build Tools, you need to port your IDE projects to the Nios II Software Build Tools development flow.

This appendix describes the steps required to port a Nios II IDE project to the Nios II Software Build Tools development flow. The Nios II EDS includes a utility to convert Nios II IDE projects to the Software Build Tools flow.



You do not need to rewrite your Nios II IDE project's C/C++ code for use with the Software Build Tools development flow.

The Nios II Software Build Tools development flow provides a number of advantages over the Nios II IDE development flow. You might want to port an IDE project to the Software Build Tools to take advantage of the following improvements:

- Fully repeatable control over all build options using command line options, Tcl scripts, or both
- Simplified project file management and naming
- Simplified makefiles
- Versioned device drivers
- Independence from Eclipse code and Eclipse projects
- Self-contained BSPs, making hand-off and version control easier than is possible with Nios II IDE-created BSPs (system library projects)
- Upwards compatibility with future releases of the Nios II EDS

### Converting a Nios II IDE Project

This section describes how to convert a Nios II IDE project to a Software Build Tools project using the **nios2-convert-ide2sbt** utility.

1. Build the original project in the Nios II IDE, using either the Debug or the Release configuration, depending on your preference. Ensure that the project builds without errors.



The Nios II Software Build Tools flow does not include separate Debug and Release builds as implemented in the Nios II IDE development flow.

2. Launch the Nios II Command Shell.



For details about the Nios II Command Shell, refer to the *Getting Started from the Command Line* chapter of the *Nios II Software Developer's Handbook*.

3. Run **nios2-convert-ide2sbt**. The command syntax is as follows:

```
nios2-convert-ide2sbt --input-dir=<source directory> \  
  --output-dir=<target directory> \  
  --build-config=<configuration>
```

The command arguments are as follows:

- *<source directory>*—directory containing the original Nios II IDE project.
- *<target directory>*—directory where **nios2-convert-ide2sbt** places the converted Software Build Tools project. If *<target directory>* does not exist, **nios2-convert-ide2sbt** creates it.
- *<configuration>*—Debug or Release, designating the Nios II IDE project configuration.

Nios II IDE project types are converted as shown in [Table A-17](#).

**Table A-17.** Conversion of Project Types by nios2-convert-ide2sbt

Nios II IDE Project Type	Software Build Tools Conversion
Nios II C/C++ system library	BSP
Nios II C/C++ library	User library (1)
Nios II C/C++ application	Application project (1)
<b>Note to Table A-17:</b> (1) At the same time, <b>nios2-convert-ide2sbt</b> converts any Nios II C/C++ system library or Nios II C/C++ libraries on which the converted project depends.	

For example, suppose you have a Nios II C/C++ application in the Release configuration, located in the **./software/hello\_world** directory. To convert the project and its associated system library, and put the resulting Software Build Tools project in the **./software\_sbt** directory, type:

```
nios2-convert-ide2sbt --input-dir=software/hello_world \
    --output-dir=software_sbt --build-config=Release ↵
```



If you need to reconvert a project you previously converted, you must delete the previous target directory, or specify a new target directory.

**nios2-convert-ide2sbt** converts your Nios II IDE software project to equivalent Software Build Tools projects. **nios2-convert-ide2sbt** ports compiler flags, like the optimization level, debug, and custom instruction options, to the new project. During conversion, **nios2-convert-ide2sbt** displays the converted project settings on the console, in the form of a sample Software Build Tools command line.



For details about Software Build Tools command usage, refer to the *Nios II Software Build Tools* and *Nios II Software Build Tools Reference* chapters of the *Nios II Software Developer's Handbook*.

## Other Software Modules

This section describes how to convert and incorporate the following kinds of software modules that you might need to include in your converted BSP:

- Custom device drivers and software components
- Precompiled libraries and non-HAL device drivers

## Custom Device Drivers and Software Components

In the Nios II IDE development flow, a makefile fragment named **component.mk** specifies device drivers. By contrast, in the Nios II Software Build Tools development flow, a Tcl script defines the device driver structure. If you have custom device drivers and software components, including third-party device drivers, convert them to Tcl scripts manually.



For more information about implementing device drivers and software packages for the Nios II Software Build Tools, refer to “Device Drivers and Software Packages” in the *Nios II Software Build Tools* chapter of the *Nios II Software Developer’s Handbook*.

## Precompiled Libraries and Non-HAL Device Drivers

If you have precompiled libraries and non-HAL device drivers, including third-party libraries and device drivers, convert them manually.

The best way to convert a typical precompiled library is to create a software package. If the precompiled library is dependent on a specific hardware device, it is better to incorporate the library into the device driver. Library archive files (.a) can be incorporated into a device driver just as C source files (.c) and header files (.h) are.



Non-HAL device drivers do not support initialization through `alt_sys_init()`.



For information about creating software packages and drivers, refer to “Integrating a Device Driver in the HAL” in the *Developing Device Drivers for the Hardware Abstraction Layer* chapter of the *Nios II Software Developer’s Handbook*.

**nios2-convert-ide2sbt** does not convert GNU Compiler Collection (GCC) command-line options for external include file paths (`-I`) or external library file paths (`-L`, `-l`). You must handle these cases manually.

To add include paths to a BSP, use the `hal.make.bsp_inc_dirs` BSP setting in your Tcl script.

To add libraries to an application, add or modify one of the following variables in the application makefile:

- **APP\_LIBRARY\_DIRS**—Specifies a list of paths to directories in which **lib<libname>.a** files reside.
- **APP\_LIBRARY\_NAMES**—Specifies a list of the names of the libraries being added. If the library file is named **lib<libname>.a**, specify **<libname>** as the name of the library.

## Using Your Converted Project

When you have finished porting your project, you can manage the makefiles, build and run the project, and perform all other project tasks exactly as if the project were created with the Software Build Tools. You can also import the project to the Software Build Tools for Eclipse for debugging.



Nios II IDE projects cannot be directly imported to the Software Build Tools for Eclipse. You must first convert the project to the Software Build Tools, according to the procedures in this section.

## Archiving Nios II IDE Software Projects

This section helps you identify the files you must include when archiving a Nios II IDE software project. With this information, you can archive a Nios II application project and its associated Nios II BSP project.

You may want to archive your projects for one of the following reasons:

- To place them under source control
- To create backups
- To bundle the projects for transfer to another location

This section covers the following information:

- How to find and identify the files that you must include in an archived Nios II IDE software project.
- Which files must have write permission to allow the software projects to be built.

## Required Files

This section describes the files required by Nios II IDE software projects. This is the minimum set of files needed to completely rebuild a software project, including the Executable and Linking Format File (.elf).

Archive your Nios II IDE software projects together with the SOPC Builder system on which they are based. You cannot rebuild a Nios II IDE software project without its associated SOPC Builder system.

### Nios II Application Project Files

The files listed in [Table A-18](#) are located in the Nios II application project directory.

**Table A-18.** Files Required for a Nios II Application Project

File Description	File Name	Write Permission Required? (1)
All source files	for example: <b>app.c</b> , <b>header.h</b> , <b>assembly.s</b> , <b>lookuptable.dat</b>	No
Eclipse project file	<b>.project</b>	No
C/C++ Development Toolkit project file	<b>.cdtproject</b>	Yes
C/C++ Development Toolkit option file	<b>.cdtbuild</b>	No
Software configuration file	<b>application.stf</b>	No

**Note to [Table A-18](#):**

(1) For further information about write permissions, refer to “[File Write Permissions](#)”.

### Nios II BSP Project

The files listed in [Table A-19](#) are located in the Nios II BSP (system library) project directory.

**Table A-19.** Files Required for a Nios II BSP Project

File description	File name	Write permission required? (1)
Eclipse project file	.project	Yes
C/C++ Development Toolkit project file	.cdtproject	Yes
C/C++ Development Toolkit option file	.cdtbuild	No
System software configuration file	system.stf	Yes

**Note to Table A-19:**

(1) For further information about write permissions, see “File Write Permissions”.

## File Write Permissions

You must have write permission for certain files, shown in [Table A-18](#) and [Table A-19](#). The tools write to these files as part of the build process. If the files are not writable, the tool chain fails.

Many source control tools mark local files read-only by default. In this case, you must override this behavior. You do not have to check the files out of source control unless you are modifying the Nios II software project.

## Help System

The Nios II IDE help system provides documentation on all IDE topics. To launch the help system, click **Help Contents** on the Help menu. You can also press F1 on Windows (Shift-F1 on Linux) at any time for context-sensitive help. The Nios II IDE help system contains hands-on tutorials that guide you step-by-step through the process of creating, building, and debugging Nios II projects.

## Referenced Documents

This chapter references the following documents:

- [Overview](#) chapter of the *Nios II Software Developer's Handbook*
- [Getting Started with the Graphical User Interface](#) chapter of the *Nios II Software Developer's Handbook*
- [Getting Started from the Command Line](#) chapter of the *Nios II Software Developer's Handbook*
- [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*
- [Nios II Software Build Tools Reference](#) chapter of the *Nios II Software Developer's Handbook*

## Document Revision History

Table A-20 shows the revision history for this document.

**Table A-20.** Document Revision History (Part 1 of 2)

Date & Document Version	Changes Made	Summary of Changes
November 2009 v9.1.0	<ul style="list-style-type: none"> <li>■ <i>Nios II Integrated Development Environment</i> chapter combined with <i>Appendix A, Porting Nios II IDE Projects to the Software Build Tools</i>. Chapter replaced by <i>Getting Started with the Graphical User Interface</i> chapter).</li> <li>■ Include Nios II IDE-specific content from the following chapters: <ul style="list-style-type: none"> <li>■ <i>Overview</i></li> <li>■ <i>Developing Programs Using the Hardware Abstraction Layer</i></li> <li>■ <i>Developing Device Drivers for the Hardware Abstraction Layer</i></li> <li>■ <i>Exception Handling</i></li> <li>■ <i>MicroC/OS-II Real-Time Operating System</i></li> <li>■ <i>Ethernet and the NicheStack TCP/IP Stack - Nios II Edition</i></li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>■ Nios II Software Build Tools for Eclipse introduced</li> <li>■ Nios II IDE deprecated</li> </ul>
March 2009 v9.0.0	<ul style="list-style-type: none"> <li>■ Reorganized and updated information and terminology to clarify role of Nios II Software Build Tools.</li> <li>■ Corrected minor typographical errors.</li> </ul>	
May 2008 v8.0.0	No change from previous release.	
October 2007 v7.2.0	<b>altera.components</b> project added	<b>altera.components</b> project added
May 2007 v7.1.0	<ul style="list-style-type: none"> <li>■ Added instructions for importing Software Build Tools projects</li> <li>■ Changed chapter title.</li> <li>■ Added table of contents to “Introduction” section.</li> <li>■ Added Referenced Documents section.</li> </ul>	Nios II Software Build Tools
March 2007 v7.0.0	No change from previous release.	
November 2006 v6.1.0	Describes updated look and feel, including Nios II C/C++ perspective and Nios II C/C++ Projects views, renamed project types.	Updated look and feel based on Eclipse 3.2.
May 2006 v6.0.0	No change from previous release.	
October 2005 v5.1.0	Updated for the Nios II IDE version 5.1.	
May 2005 v5.0.0	No change from previous release.	

**Table A-20.** Document Revision History (Part 2 of 2)

<b>Date &amp; Document Version</b>	<b>Changes Made</b>	<b>Summary of Changes</b>
September 2004 v1.1	Updated screen shots.	
May 2004 v1.0	Initial Release.	



## How to Find Further Information

This handbook is one part of the complete Nios II processor documentation. The following references are also available.

- The *Nios II Processor Reference Handbook* describes the Nios II processor from a high-level conceptual description to the low-level details of implementation.
- The *Quartus II Handbook, Volume 5: Embedded Peripherals* discusses Altera-provided peripherals and Nios II drivers which are included with the Quartus II software.
- The Nios II integrated development environment (IDE) provides tutorials and complete reference for using the features of the graphical user interface. The help system is available after launching the Nios II IDE.
- Altera's on-line solutions database is an internet resource that offers solutions to frequently asked questions via an easy-to-use search engine. You can access the database from the [Knowledge Database](#) page of the Altera website.
- Altera application notes and tutorials offer step-by-step instructions on using the Nios II processor for a specific application or purpose. You can obtain these documents from the [Literature: Nios II Processor](#) page of the Altera website.

## How to Contact Altera

For the most up-to-date information about Altera products, refer to the following table.






Contact <i>(Note 1)</i>	Contact Method	Address
Technical support	Website	<a href="http://www.altera.com/support">www.altera.com/support</a>
Technical training	Website	<a href="http://www.altera.com/training">www.altera.com/training</a>
	Email	<a href="mailto:custrain@altera.com">custrain@altera.com</a>
Altera literature services	Email	<a href="mailto:literature@altera.com">literature@altera.com</a>
Non-technical support (General) (Software Licensing)	Email	<a href="mailto:nacomp@altera.com">nacomp@altera.com</a>
	Email	<a href="mailto:authorization@altera.com">authorization@altera.com</a>

**Note:**

- (1) You can also contact your local Altera sales office or sales representative.

## Typographic Conventions

The following table shows the typographic conventions that this document uses.

Visual Cue	Meaning
<b>Bold Type with Initial Capital Letters</b>	Indicates command names, dialog box titles, dialog box options, and other GUI labels. For example, <b>Save As</b> dialog box.
<b>bold type</b>	Indicates directory names, project names, disk drive names, file names, file name extensions, and software utility names. For example, <b>\qdesigns</b> directory, <b>d:</b> drive, and <b>chiptrip.gdf</b> file.
<i>Italic Type with Initial Capital Letters</i>	Indicates document titles. For example, <i>AN 519: Stratix® IV Design Guidelines</i> .
<i>Italic type</i>	Indicates variables. For example, $n + 1$ . Variable names are enclosed in angle brackets (< >). For example, <file name> and <project name>. <b>.pof</b> file.
Initial Capital Letters	Indicates keyboard keys and menu names. For example, Delete key and Options menu.
"Subheading Title"	Quotation marks indicate references to sections within a document and titles of Quartus II Help topics. For example, "Typographic Conventions".
Courier type	Indicates signal, port, register, bit, block, and primitive names. For example, data1, tdi, and input. Active-low signals are denoted by suffix n. For example, resetn. Indicates command line commands and anything that must be typed exactly as it appears. For example, c:\qdesigns\tutorial\chiptrip.gdf. Also indicates sections of an actual file, such as a Quartus II report file, references to parts of files (for example, the AHDL keyword SUBDESIGN), and logic function names (for example, TRI).
1., 2., 3., and a., b., c., and so on.	Numbered steps indicate a list of items when the sequence of the items is important, such as the steps listed in a procedure.
■ ■	Bullets indicate a list of items when the sequence of the items is not important.
	The hand points to information that requires special attention.
	A caution calls attention to a condition or possible situation that can damage or destroy the product or your work.
	A warning calls attention to a condition or possible situation that can cause you injury.
	The angled arrow instructs you to press the Enter key.
	The feet direct you to more information about a particular topic.