Cortex-M™ System Design Kit

Revision: r0p0

Technical Reference Manual

ARM DDI 0479B (ID070811)

Cortex-M System Design Kit
Technical Reference Manual

Release Information

The following changes have been made to this document:

Change history

Date	Issue	Confidentiality	Change
14 March 2011	A	Non-Confidential	First release for r0p0
16 June 2011	B	Non-Confidential	Second release for r0p0

Proprietary Notice

Confidentiality Status

Product Status

The information in this document is final, that is for a developed product.

Web Address

`http://www.arm.com`

Contents
Cortex-M System Design Kit Technical Reference Manual

Preface

This preface introduces the *Cortex-M System Design Kit Technical Reference Manual*. It contains the following sections:

- *About this book* on page vi
- *Feedback* on page x.

About this book

This is the *Technical Reference Manual* (TRM) for the Cortex-M System Design Kit.

Product revision status

The r*n*p*n* identifier indicates the revision status of the product described in this book, where:

r*n*	Identifies the major revision of the product.
p*n*	Identifies the minor revision or modification status of the product.

Intended audience

This book is written for system designers to design products with the ARM Cortex-M processors.

Using this book

This book is organized into the following chapters:

Chapter 1 *Introduction*

Read this for an introduction to the Cortex-M System Design Kit.

Chapter 2 *Functional Description*

Read this for an overview of the major functional blocks and the operation of the Cortex-M System Design Kit.

Chapter 3 *Basic AHB Components*

Read this for a description of the AHB components that the Cortex-M System Design Kit uses.

Chapter 4 *APB Components*

Read this for a description of the APB components that the Cortex-M System Design Kit uses.

Chapter 5 *Advanced AHB Components*

Read this for a description of the advanced AHB components that the Cortex-M System Design Kit uses.

Chapter 6 *Behavioral Memory Models*

Read this for a description of the behavioral memory models that the Cortex-M System Design Kit uses.

Chapter 7 *Verification Components*

Read this for a description of the verification components in the Cortex-M System Design Kit.

Appendix A *Revisions*

Read this for a description of the technical changes between released issues of this book.

Glossary

The *ARM Glossary* is a list of terms used in ARM documentation, together with definitions for those terms. The *ARM Glossary* does not contain terms that are industry standard unless the ARM meaning differs from the generally accepted meaning.

The *ARM Glossary* is available on the ARM Infocenter at,
`http://infocenter.arm.com/help/topic/com.arm.doc.aeg0014-/index.html`

Typographical Conventions

Conventions that this book can use are described in:

- *Typographical*
- *Timing diagrams*
- *Signals* on page viii.

Typographical

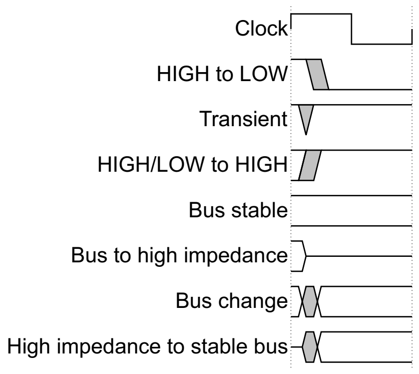
The typographical conventions are:

italic	Highlights important notes, introduces special terminology, denotes internal cross-references, and citations.
bold	Highlights interface elements, such as menu names. Denotes signal names. Also used for terms in descriptive lists, where appropriate.
`monospace`	Denotes text that you can enter at the keyboard, such as commands, file and program names, and source code.
<u>`mono`</u>`space`	Denotes a permitted abbreviation for a command or option. You can enter the underlined text instead of the full command or option name.
`monospace italic`	Denotes arguments to monospace text where the argument is to be replaced by a specific value.
`monospace bold`	Denotes language keywords when used outside example code.
< and >	Enclose replaceable terms for assembler syntax where they appear in code or code fragments. For example: `MRC p15, 0 <Rd>, <CRn>, <CRm>, <Opcode_2>`

Timing diagrams

The figure named *Key to timing diagram conventions* explains the components used in timing diagrams. Variations, when they occur, have clear labels. You must not assume any timing information that is not explicit in the diagrams.

Shaded bus and signal areas are undefined, so the bus or signal can assume any value within the shaded area at that time. The actual level is unimportant and does not affect normal operation.



Key to timing diagram conventions

Signals

The signal conventions are:

Signal-level	The level of an asserted signal depends on whether the signal is active-HIGH or active-LOW. Asserted means: • HIGH for active-HIGH signals • LOW for active-LOW signals.
Lower-case n	At the start or end of a signal name denotes an active-LOW signal.

Additional reading

This section lists publications by ARM and by third parties.

See Infocenter, `http://infocenter.arm.com`, for access to ARM documentation.

ARM publications

This book contains information that is specific to this product. See the following document for other relevant information:

- *Cortex-M0 System Design Kit Example System Guide* (ARM DUI 0559)
- *Cortex-M System Design Kit Example System Guide* (ARM DUI 0594)
- *Cortex-M0 Technical Reference Manual* (ARM DDI 0432)
- *Cortex-M3 Technical Reference Manual* (ARM DDI 0337)
- *Cortex-M4 Technical Reference Manual* (ARM DDI 0439).

Other publications

This section lists relevant documents published by third parties:

- JEDEC website, `www.jedec.org`
- Accellera website, `www.accellera.org`.

Feedback

ARM welcomes feedback on this product and its documentation.

Feedback on this product

If you have any comments or suggestions about this product, contact your supplier and give:

- The product name.
- The product revision or version.
- An explanation with as much information as you can provide. Include symptoms and diagnostic procedures if appropriate.

Feedback on content

If you have comments on content then send an e-mail to `errata@arm.com`. Give:

- the title
- the number, ARM DDI 0479B
- the page numbers to which your comments apply
- a concise explanation of your comments.

ARM also welcomes general suggestions for additions and improvements.

Chapter 1
Introduction

This chapter describes the Cortex-M System Design Kit. It contains the following sections:

- *About the Cortex-M System Design Kit* on page 1-2
- *Product revisions* on page 1-4.

1.1 About the Cortex-M System Design Kit

The Cortex-M System Design Kit helps you design products using ARM Cortex-M processors.

The design kit contains:

- a selection of AHB and APB components, including several peripherals such as GPIO, timers, watchdog, and UART
- an example system for supported processor products
- example synthesis scripts for the example system
- example compilation and simulation scripts for the Verilog environment that supports ModelSim, VCS, and NC Verilog
- example code for software drivers
- example test code to demonstrate various operations of the systems
- example compilation scripts and project files for software that supports the ARM RealView Development Suite, Keil Microcontroller Development Kit, and CodeSourcery g++ Lite
- documentation including:
  - *Cortex-M™ System Design Kit Technical Reference Manual*
  - *Cortex-M0™ System Design Kit Example System Guide*
  - *Cortex-M™ System Design Kit Example System Guide*.

Figure 1-1 shows the use of the design kit in various stages of a design process.

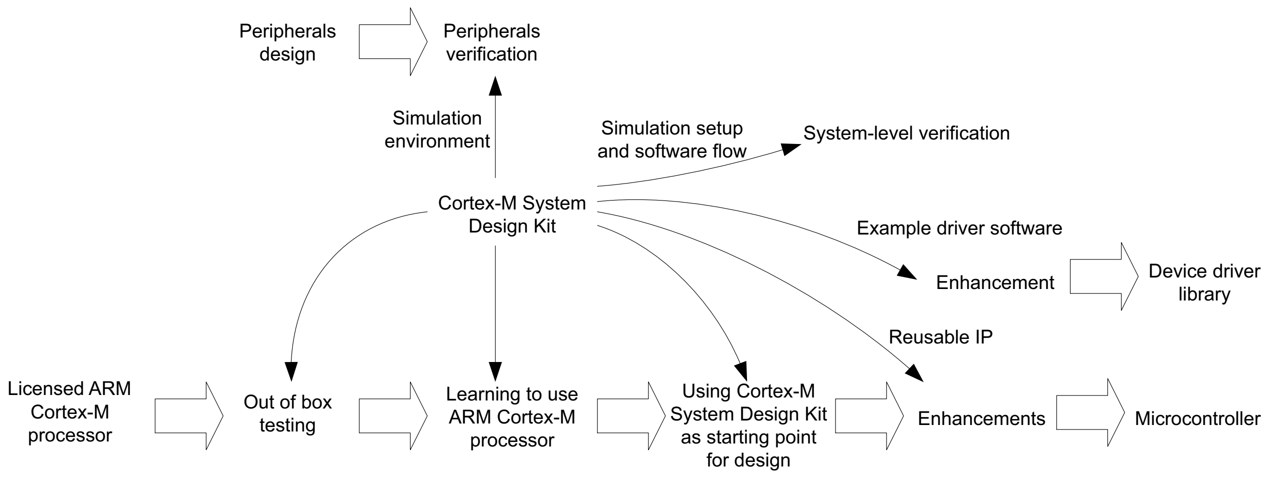

Peripherals design
Peripherals verification
Simulation environment
Simulation setup and software flow
System-level verification
Cortex-M System Design Kit
Example driver software
Enhancement
Device driver library
Reusable IP
Licensed ARM Cortex-M processor
Out of box testing
Learning to use ARM Cortex-M processor
Using Cortex-M System Design Kit as starting point for design
Enhancements
Microcontroller

Figure 1-1 Cortex-M System Design Kit usage in various stages of a design process

Table 1-1 shows the Cortex-M System Design Kit usage in various stages of a design process.

Table 1-1 Cortex-M System Design Kit usage in various stages of a design process

Area	Description
Out of box (OoB) testing	When you license the Cortex-M System Design Kit and a Cortex-M processor, you can use it for OoB testing and benchmarking
Learning	Using the example systems, you can learn how to integrate the Cortex-M processor, and carry out various operations
Starting point of design	You can use the Cortex-M System Design Kit as a starting point to design your microcontrollers or *System-on-Chip* (SoC) products
Verification	You can use the example system in the Cortex-M System Design Kit as a verification environment to carry out system-level verification
Starting point of software driver	You can use the example software code in the Cortex-M System Design Kit as a starting point for software driver development
Reusable IP	You can reuse the various components of the Cortex-M System Design Kit in microcontroller or SoC design projects

The Cortex-M System Design Kit is available as:

- Cortex-M0 System Design Kit. This supports Cortex-M0 and Cortex-M0 DesignStart.
- Cortex-M System Design Kit, full version. This supports Cortex-M0, Cortex-M0 DesignStart, Cortex-M3, and Cortex-M4.

The other differences between the Cortex-M0 and Cortex-M versions of the design kit are the example systems, and the components provided. See Figure 1-2.

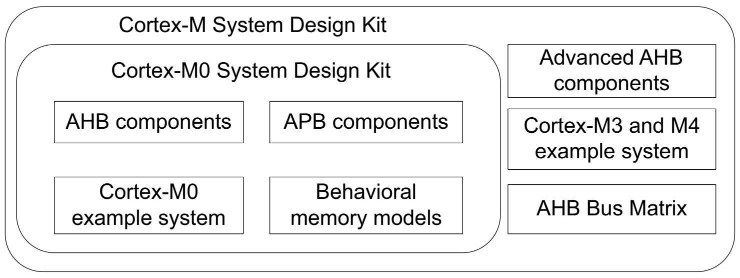


Figure 1-2 Difference between the two versions of the design kit

1.2 Product revisions

This section describes the differences in functionality between product revisions of the Cortex-M System Design Kit:

r0p0	First release.

Chapter 2
Functional Description

This chapter describes the major functional blocks of the Cortex-M System Design Kit. It contains the following sections:

2.1 About the Cortex-M System Design Kit components

The Cortex-M System Design Kit provides example systems with AHB and APB components designed for low-power and low-latency designs.

The pre-configured and validated examples enable you to develop devices in very short design cycles. In addition, you can reuse the components in future designs.

2.2 Design components

The example systems consist of the following components and models:

- *Basic AHB components*
- *APB components* on page 2-4
- *Advanced AHB components* on page 2-5
- *Behavioral memory models* on page 2-6.

2.2.1 Basic AHB components

This section summarizes the basic AHB components. See Chapter 3 *Basic AHB Components*.

Example AHB slave

The example AHB slave provides 16 bytes of hardware R/W registers, that are, organized as 4 words, each of them is byte addressable. It demonstrates the implementation of a simple AHB slave.

AHB default slave

The AHB default slave returns an error response when a transaction access an invalid address.

AHB slave multiplexer

The AHB slave multiplexer:

- is an eight-input AHB slave multiplexer
- uses parameters to define the slave ports usage.

AHB master multiplexer

The AHB master multiplexer:

- is a three-input AHB master multiplexer
- uses parameters to define the master ports usage.

AHB *General Purpose Input/Output* (GPIO)

The AHB GPIO provides a 16 bits I/O interface with:

- interrupt generation capability
- registers for alternate function switching
- masked access support.

AHB to APB sync-down bridge

The AHB to APB bridge:

- supports APB2, APB3, and APB4 protocols
- permits APB to run at a clock rate which is same or divided from AHB clock.

AHB to SRAM interface module

The AHB to SRAM interface module:

- connects an on-chip synchronous SRAM block to the AHB interface for zero wait state accesses

- connects an *Field Programmable Gate Array* (FPGA) block RAM to the AHB interface in FPGA development.

AHB to flash interface module

The AHB to flash interface module:

- is a simple 32 bits interface module that includes a wait state generator to connect read-only memories with wait states
- connects the simple read-only memory models to the AHB interface.

AHB timeout monitor

The AHB timeout monitor:

- Issues an error response to a stalled transfer. This prevents an AHB slave from locking up the system.
- Uses Verilog parameter to specify the timeout period.

AHB to external SRAM interface

The AHB to external SRAM interface:

- connects static memory devices, or external peripherals to the AHB interface
- supports 16 bits and 8 bits external interfaces.

AHB bit-band wrapper for Cortex- M0

The AHB bit-band wrapper provides the ability to address bits in memory as an atomic operation by aliasing individual bits to word aligned addresses.

2.2.2 APB components

This section summarizes the APB components. See Chapter 4 *APB Components*.

Example APB slaves

The example APB slave provides 16 bytes of hardware R/W registers, that are, organized as 4 words, and demonstrate the implementation of simple APB slave.

Timer

The timer is a 32 bits down-counter with the following features:

- generates an interrupt request when the counter value reaches 0
- uses an internal enable control or an external input as timer enable
- runs on the peripheral clock or the rising edge of an external input.

APB UART

The UART supports 8 bits communication with programmable baud rate and interrupt generation.

Dual timer

The dual timer contains two 32 bits timer modules. You can configure each timer module as 32 bits mode or 16 bits mode supporting the following configurations:

- free running
- auto-reload
- one-shot.

Watchdog

This is a 32 bits watchdog timer for interrupt and reset generation functions.

APB slave multiplexer

The APB slave multiplexer:

- supports up to 16 APB slaves
- uses four bits of the **PADDR** signal to generate the **PSEL** signal
- handles the read data and response multiplexing.

APB subsystem

The APB subsystem is a common platform for all the example systems in the Cortex-M System Design Kit. It contains:

- APB timers
- APB UARTs
- a dual timer
- watchdog
- an AHB to APB bridge
- optional *Interrupt Request* (IRQ) synchronizer.

APB timeout monitor

The APB timeout monitor:

- prevents an APB slave from locking up the system
- is placed between the APB master and the APB slave, and directly connected to the APB slave.

2.2.3 Advanced AHB components

This section summarizes the advanced AHB components. See Chapter 5 *Advanced AHB Components*.

——— **Note** ———

The advanced AHB components are available only with the Cortex-M System Design Kit, full version. They are not included in the Cortex-M0 System Design Kit.

———————

AHB bus matrix

The AHB bus matrix component is optimized for low-latency systems. It permits multiple AHB masters and AHB slaves to connect together.

AHB upsizer

The AHB upsizer enables a 32 bits AHB master to connect to a 64 bits AHB slave.

AHB downsizer

The AHB downsizer enables a 64 bits AHB master to connect to a 32 bits AHB slave.

AHB to APB asynchronous bridge

The AHB to APB asynchronous bridge supports AHB to APB2, APB3, and APB4.

AHB to AHB synchronous bridge

The AHB to AHB synchronous bridge provides timing isolation in large AHB systems.

AHB to AHB sync-down bridge

The AHB to AHB synchronous down-conversion bridge syncs-down the AHB domain from a higher frequency to a lower frequency.

AHB to AHB sync-up bridge

The AHB to AHB synchronous up-conversion bridge syncs-up the AHB domain from a lower frequency to a higher frequency.

2.2.4 Behavioral memory models

This section summarizes the memory models. See Chapter 6 *Behavioral Memory Models*.

ROM model wrapper

The ROM model wrapper enables easy switching between different implementations of ROM.

RAM model wrapper

The RAM model wrapper enables easy switching between different implementations of RAM.

Behavioral SRAM model with AHB interface

The behavioral SRAM model with AHB interface enables you to:

- define the initial memory image
- configurable wait states for the AHB NON-SEQUENTIAL transfers and SEQUENTIAL transfers.

32-bit flash ROM behavioral model

This is a simple behavioral model for 32 bits flash memory.

SRAM synthesizable model

This is a model for SRAM that behaves like simple synchronous RAM in ASIC or FPGA.

FPGA ROM

This model behaves like simple synchronous RAM in FPGA.

External asynchronous 8-bit SRAM

This is a simple behavioral model for 8 bits external SRAM. You can use the AHB to external memory interface to connect the SRAM model to the AHB system.

External asynchronous 16-bit SRAM

This is a simple behavioral model for 16 bits external SRAM. It supports 16 bits and 8 bits write operations. You can use the AHB to external memory interface to connect the SRAM model to the AHB system.

2.3 Verification components

This section summarizes the verification components. See Chapter 7 *Verification Components*.

2.3.1 AHB protocol checker

The AHB protocol checker is useful for detecting bus protocol violations during simulation. The design is based on the *Open Verification Library* (OVL).

2.3.2 AHB-Lite protocol checker

The AHB-Lite protocol checker is useful for detecting bus protocol violations during simulation.

2.3.3 APB protocol checkers

The APB protocol checkers are useful for detecting bus protocol issues in APB systems. It supports APB3 and APB4.

2.3.4 AHB *File Reader Bus Master* (FRBM)

The AHB FRBM enables you to stimulate the AHB systems quickly and efficiently. You can use it to generate explicit AHB bus transfers.

2.4 ID registers in programmable components

In the Cortex-M System Design Kit, some of the peripherals contain a number of read-only *Identification* (ID) registers. These ID registers enable software to extract the component type and revision information. In some cases, these registers are required to enable device driver software to work with different versions of the same peripherals.

One of the ID registers, PID3 contains an *Engineering Change Order* (ECO) bit field generated from the **ECOREVNUM[3:0]** input signal.

The ECO operation permits you to carry out minor design changes in the late stage of a chip design process, for example, at silicon mask level. In most designs, you can tie this input signal LOW, or you can connect to tie-off cells if ECO revision maintenance is required.

The ID registers are not strictly required for peripheral operation. In ultra low-power designs, you can remove these ID registers to reduce gate count and power consumption.

When you modify a peripheral from the Cortex-M System Design Kit, modify the JEDEC ID value and the part number within the ID registers to indicate that the peripheral is no longer identical to the original version from ARM. Alternatively you can remove these ID registers.

JEDEC standard describes the JEDEC ID value allocation.

2.4.1 Modification of components

In some applications, it is necessary to modify the design of some components. If this is required, ARM recommends that you do the following:

- Change the component name and filename to avoid confusion, especially, if you are running multiple projects using Cortex-M System Design Kit components.
- Update the ID registers value. See *ID registers in programmable components*.
- Perform your own verification and testing.

2.5 Use of OVL

The components in the Cortex-M System Design Kit contain instantiations of OVL assertion components. The OVL assertions permit errors to be detected during Verilog simulation.

The instantiation of OVL assertions are conditional:

AHB components	This is controlled by the `ARM_AHB_ASSERT_ON` macro.
APB components	This is controlled by the `ARM_APB_ASSERT_ON` macro.

You can download the OVL source code from Accellera, if you use the OVL assertion feature.

Chapter 3
Basic AHB Components

This chapter describes the AHB components provided in the Cortex-M System Design Kit. It contains the following sections:

3.1 Example AHB slave

The example AHB slave, `ahb_eg_slave.v`, demonstrates the implementation of a simple AHB slave, and consists of the `ahb_eg_slave_interface.v` and the `ahb_eg_slave_reg.v`. Figure 3-1 shows the example AHB slave module.

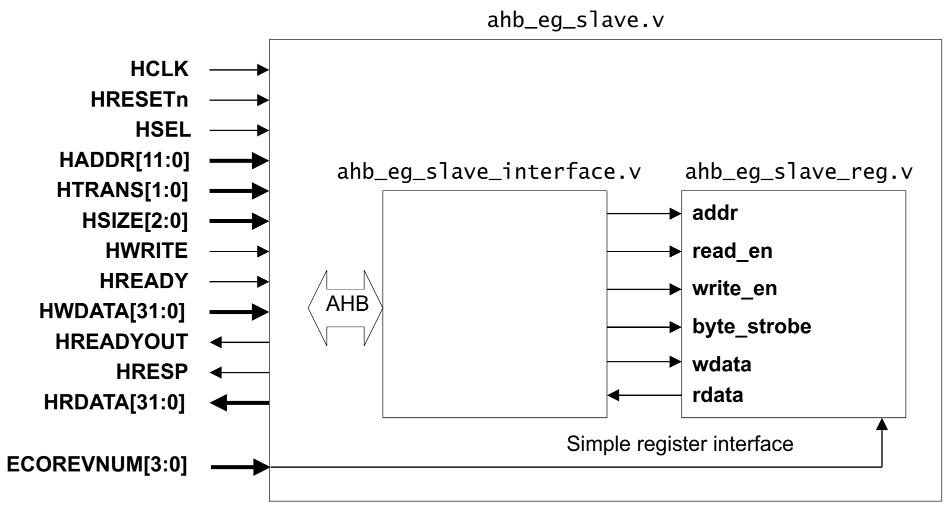


Figure 3-1 Example AHB Slave

The example AHB slave has the following features:

- 16 bytes of hardware R/W registers, that are, organized as 4 words.
- Register accesses in byte, half word, and word transfers
- Component ID and Peripheral ID registers. These read-only ID registers are optional. You must modify the following in these registers:
  - part number, 12 bits
  - JEDEC ID value, 7 bits.
- The **ECOREVNUM** input signal is connected to the ECO revision number in the Peripheral ID Register 3.
- The interface block converts the AHB protocol to a simple non-pipeline bus protocol. You can reuse it for porting simple peripherals from 8 bits or 16 bits products to an ARM-based system.

You can use the example AHB slave as a starting point for creating your own AHB peripherals. To do this, perform the following steps:

1. Copy the example AHB slave to a new directory, and rename the files to names of your choice.
2. Remove the register block inside the example AHB slave, and replace with your own peripheral register set.
3. Add the additional peripheral functionality, and I/O pins to the design.
4. Instantiate the peripheral design in the system, and develop verification tests.

Table 3-1 shows the characteristics of the example AHB slave module.

Table 3-1 Example AHB slave characteristics

Element name	Description	
Filename	`ahb_eg_slave.v`	
Parameters	`ADDRWIDTH`	Width of the AHB address bus. The default is 12.
Clock domain	**HCLK**	

The design provides a 4 bits **ECOREVNUM** input. This is connected to the Peripheral ID Register 3 to reflect revision changes during ECO of the chip design process. You can tie this signal LOW, or connect it to special tie-off cells so that you can change the ECO revision number at silicon netlists or a lower-level such as silicon mask.

3.1.1 Programmers model

Table 3-2 shows the example AHB slave memory map.

Table 3-2 Example AHB slave memory map

Name	Base offset	Type	Width	Reset value	Description
DATA0	`0x0000`	R/W	32	`0x00000000`	Simple data Register
DATA1	`0x0004`	R/W	32	`0x00000000`	Simple data Register
DATA2	`0x0008`	R/W	32	`0x00000000`	Simple data Register
DATA3	`0x000C`	R/W	32	`0x00000000`	Simple data Register
PID4	`0xFD0`	RO	8	`0x04`	Peripheral ID Register 4: **[7:4]** Block count. **[3:0]** jep106_c_code.
PID5[a]	`0xFD4`	RO	8	`0x00`	Peripheral ID Register 5
PID6[a]	`0xFD8`	RO	8	`0x00`	Peripheral ID Register 6
PID7[a]	`0xFDC`	RO	8	`0x00`	Peripheral ID Register 7
PID0	`0xFE0`	RO	8	`0x17`	Peripheral ID Register 0: **[7:0]** Part number[7:0].
PID1	`0xFE4`	RO	8	`0xB8`	Peripheral ID Register 1: **[7:4]** jep106_id_3_0. **[3:0]** Part number[11:8].
PID2	`0xFE8`	RO	8	`0x0B`	Peripheral ID Register 2: **[7:4]** Revision. **[3]** jedec_used. **[2:0]** jep106_id_6_4.
PID3	`0xFEC`	RO	8	`0x00`	Peripheral ID Register 3: **[7:4]** ECO revision number. **[3:0]** Customer modification number.
CID0	`0xFF0`	RO	8	`0x0D`	Component ID Register 0

Table 3-2 Example AHB slave memory map (continued)

Name	Base offset	Type	Width	Reset value	Description
CID1	`0xFF4`	RO	8	`0xF0`	Component ID Register 1
CID2	`0xFF8`	RO	8	`0x05`	Component ID Register 2
CID3	`0xFFC`	RO	8	`0xB1`	Component ID Register 3

a. The PID 5, PID 6, and PID 7 registers are not used.

Note

The signals such as **HPROT[3:0]**, **HMASTLOCK**, and **HBURST[2:0]** are not used in the design, so they do not appear in the AHB interface component.

3.2 AHB default slave

The AHB default slave, `ahb_default_slave.v`, responds to transfers when the bus master accesses an undefined address. A zero wait state OKAY response is generated for IDLE or BUSY transfers, and an ERROR response is generated for NONSEQUENTIAL or SEQUENTIAL transfers. Figure 3-2 shows the AHB default slave module.

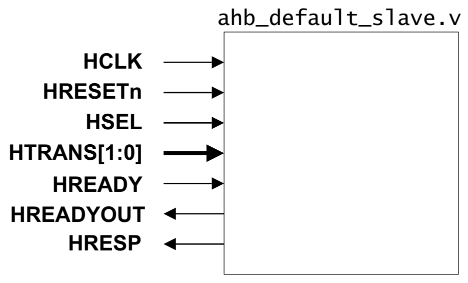


Figure 3-2 AHB default slave component

Table 3-3 shows the characteristics of the AHB default slave module.

Table 3-3 AHB default slave characteristics

Element name	Description
Filename	`ahb_default_slave.v`
Parameters	None
Clock domain	**HCLK**

3.3 AHB slave multiplexer

The AHB slave multiplexer, `ahb_slave_mux.v`, supports up to eight AHB slaves. It uses parameters to define the slave port usage so that the synthesis process does not generate unnecessary extra logic. Figure 3-3 shows the AHB slave multiplexer.

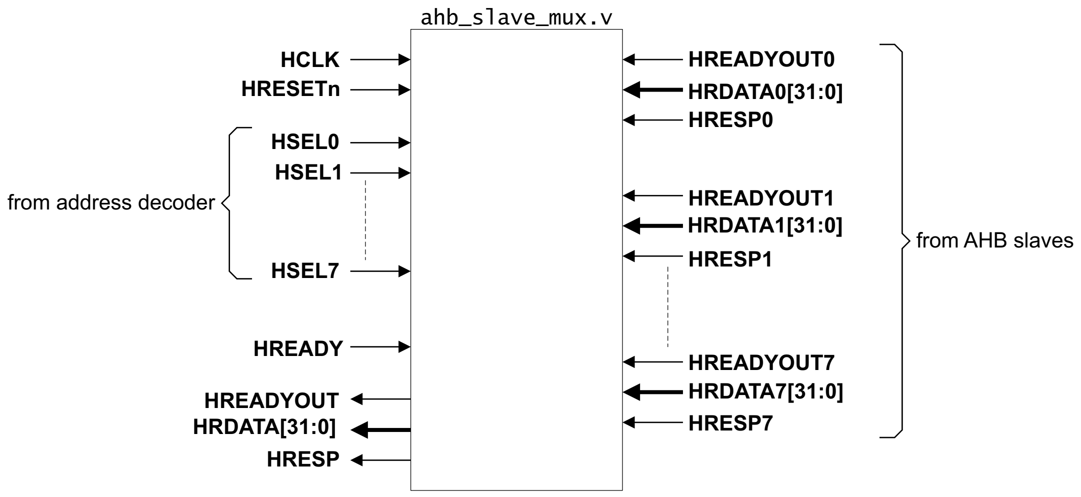


Figure 3-3 AHB slave multiplexer

The slave to master multiplexer controls the routing of read data and response signals from the system bus slaves to the bus masters. An address decoder determines the slave that is currently selected, and generates the **HSEL** signals to the AHB slave multiplexer and the AHB slaves. The multiplexer connects the outputs of the selected slave to the inputs of the bus masters. When slaves are added to, or removed from, the system, you must modify the input connections and update the corresponding Verilog parameters to this module to adapt for the changes.

Note

The **HSELx** signal that the address decoder generates must be one-hot, that is, you can set only one of the bits to 1.

A registered version of the slave select signals are used because the read data and response signals are switched during the data phase of a transfer. This registering logic is included inside the AHB slave multiplexer.

Table 3-4 shows the characteristics of the AHB slave multiplexer module.

Table 3-4 AHB slave multiplexer characteristics

Element name	Description
Filename	`ahb_slave_mux.v`
Parameters	The parameters are as follows: `PORT0_ENABLE` The supported parameter values are the following: **0** Disable port 0. **1** Enable port 0. `PORT1_ENABLE` The supported parameter values are the following: **0** Disable port 1. **1** Enable port 1. `PORT2_ENABLE` The supported parameter values are the following: **0** Disable port 2. **1** Enable port 2. `PORT3_ENABLE` The supported parameter values are the following: **0** Disable port 3. **1** Enable port 3. `PORT4_ENABLE` The supported parameter values are the following: **0** Disable port 4. **1** Enable port 4. `PORT5_ENABLE` The supported parameter values are the following: **0** Disable port 5. **1** Enable port 5. `PORT6_ENABLE` The supported parameter values are the following: **0** Disable port 6. **1** Enable port 6. `PORT7_ENABLE` The supported parameter values are the following: **0** Disable port 7. **1** Enable port 7. **Note** All `PORT`*n*`_ENABLE` are set to 1 by default. `DW` Data width. You can configure the width to either 64 bits or 32 bits. This is set to 32 by default.
Clock domain	**HCLK**

If you require more AHB slave ports, you can either cascade two AHB slave multiplexers, or expand the design.

Figure 3-4 on page 3-8 shows the cascade connection of two AHB slave multiplexers in which the **HSEL** signals for slaves 8-14 are connected to **HSEL1** to **HSEL7** of the AHB slave multiplexer 2. The **HSEL0** of the AHB slave multiplexer 2 is an OR function of the **HSEL** signal for the AHB slaves 0-7.

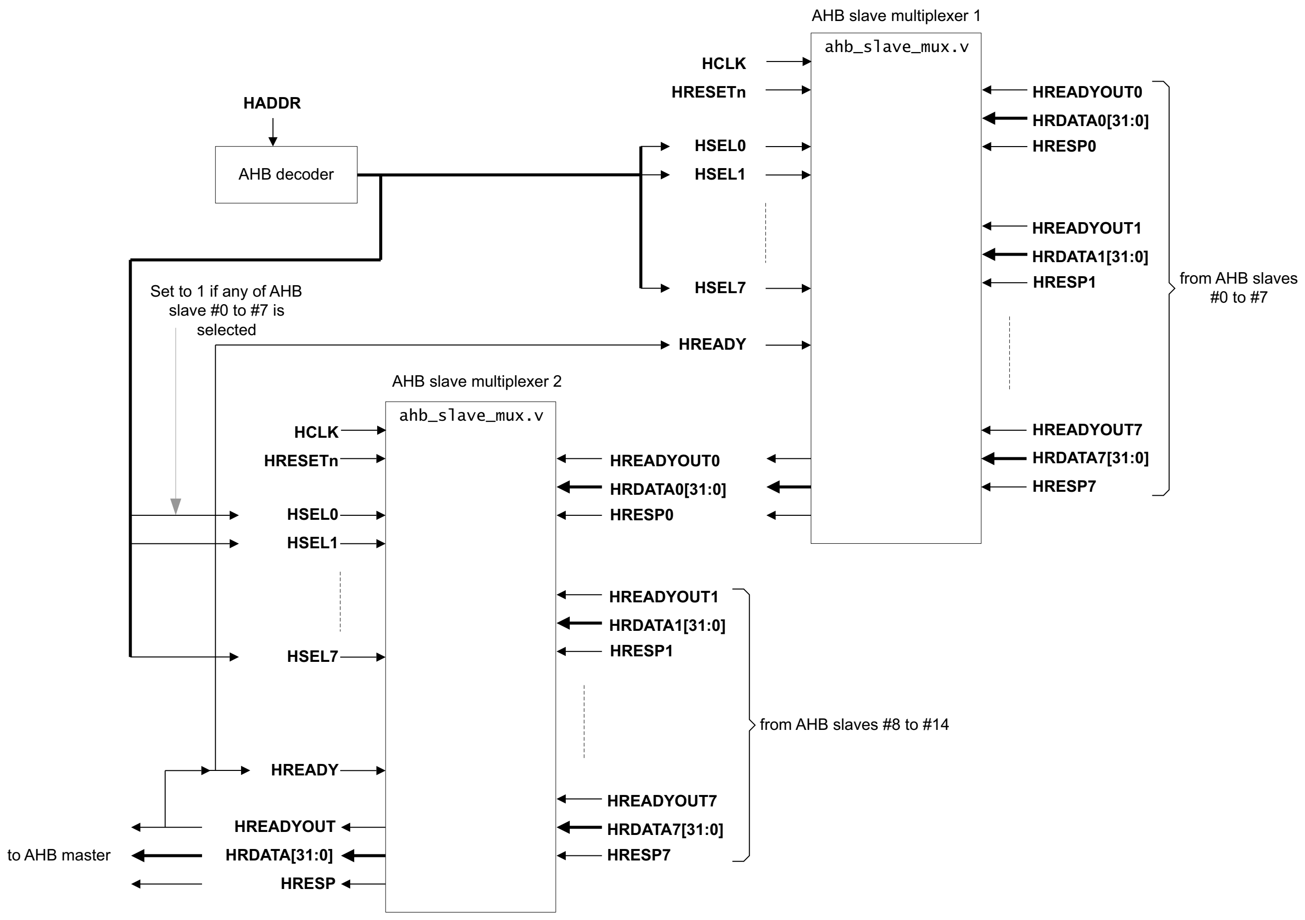


Figure 3-4 Cascade connection

Instead of using multiple slave multiplexers, you can modify the design as follows:

- copy and rename the module
- add ports for AHB slave connections
- add Verilog parameters, such as `PORT`*n*`_ENABLE` if required
- add the data phase select register, reg_hsel, and its next state logic
- add ports to the slave signal multiplexing logic
- adjust the optional OVL assertion code.

3.4 AHB master multiplexer

The AHB master multiplexer, `ahb_master_mux.v`, permits up to three AHB masters to share an AHB connection. It uses parameters to define the master port usage. Therefore, the synthesis process does not generate unnecessary additional logic. Figure 3-5 shows the AHB master multiplexer.

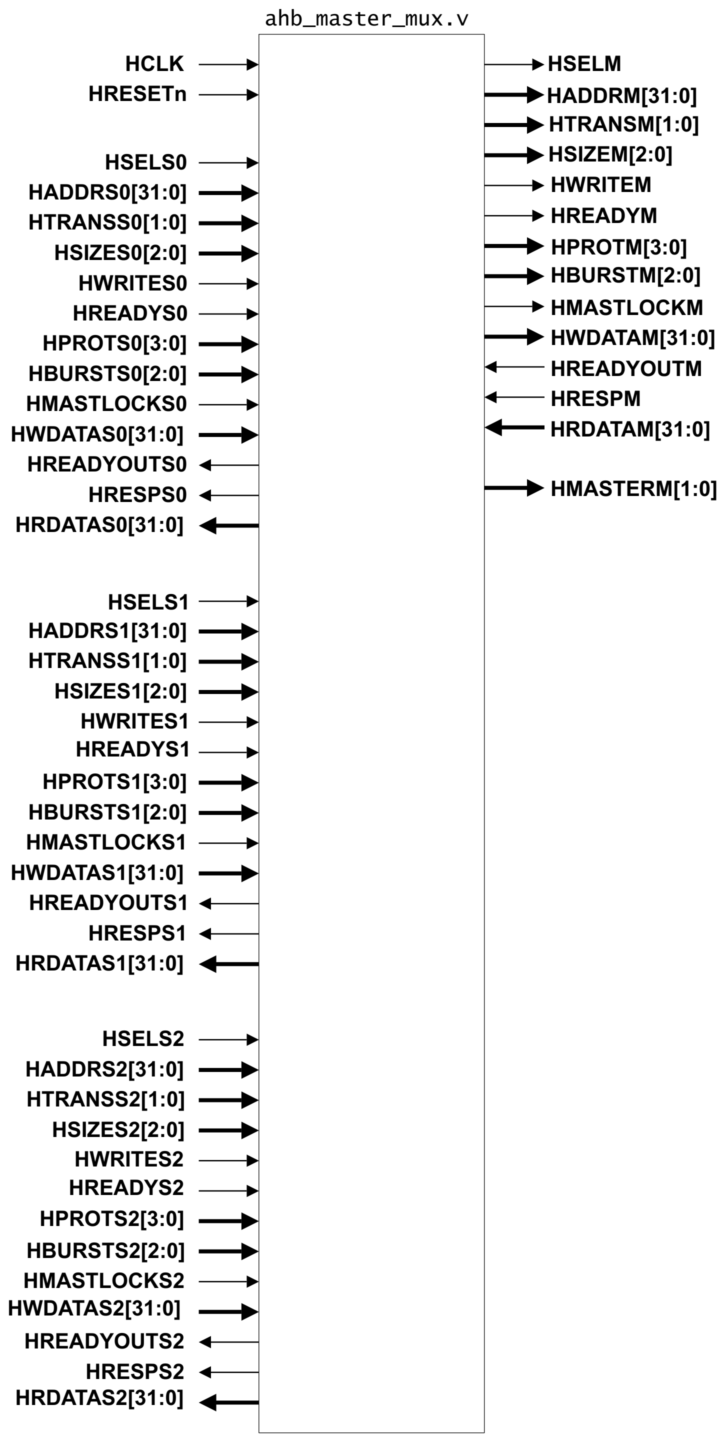


Figure 3-5 AHB master multiplexer

Table 3-5 shows the characteristics of the AHB master multiplexer.

Table 3-5 AHB master multiplexer characteristics

Element name	Description
Filename	`ahb_master_mux.v`
Parameters	The parameters are as follows: `PORT0_ENABLE` The supported parameter values are the following: **0** Disable port 0. **1** Enable port 0. `PORT1_ENABLE` The supported parameter values are the following: **0** Disable port 1. **1** Enable port 1. `PORT2_ENABLE` The supported parameter values are the following: **0** Disable port 2. **1** Enable port 2. **Note** All `PORT`*n*`_ENABLE` are set to 1 by default. `DW` Data width. You can configure the width to either 64 bits or 32 bits. This is set to 32 by default.
Clock domain	**HCLK**

3.4.1 Arbitration scheme

The AHB master multiplexer uses a fixed arbitration scheme as follows:

Port 0	Same priority as port 1, round-robin scheme.
Port 1	Same priority as port 0, round-robin scheme.
Port 2	Higher priority master.

Switch-over between different masters is disabled during a fixed length burst, locked transfers, or if a transfer is announced to the AHB slaves at the same time as a wait state occurs on the bus.

You can break an incrementing burst with an unspecified length into multiple parts as a result of arbitration. The master multiplexer forces **HTRANS** to NONSEQUENTIAL for the first transfer after switching to ensure that the AHB protocol operates correctly.

3.4.2 HMASTERM output

The AHB master multiplexer provides a 2 bits **HMASTER** output signal, **HMASTERM**:

`2'b00`	Selects port 0.
`2'b01`	Selects port 1.
`2'b10`	Selects port 2.
`2'b11`	None.

3.5 AHB GPIO

The AHB GPIO, `ahb_gpio.v`, is a general purpose I/O interface unit. It provides a 16 bits I/O interface with the following properties:

- programmable interrupt generation capability
- bit masking support using address values
- registers for alternate function switching with pin multiplexing support
- thread safe operation by providing separate set and clear addresses for control registers
- inputs are sampled using a double flip-flop to avoid meta-stability issues.

Figure 3-6 shows the control circuit and external interface of the AHB GPIO.

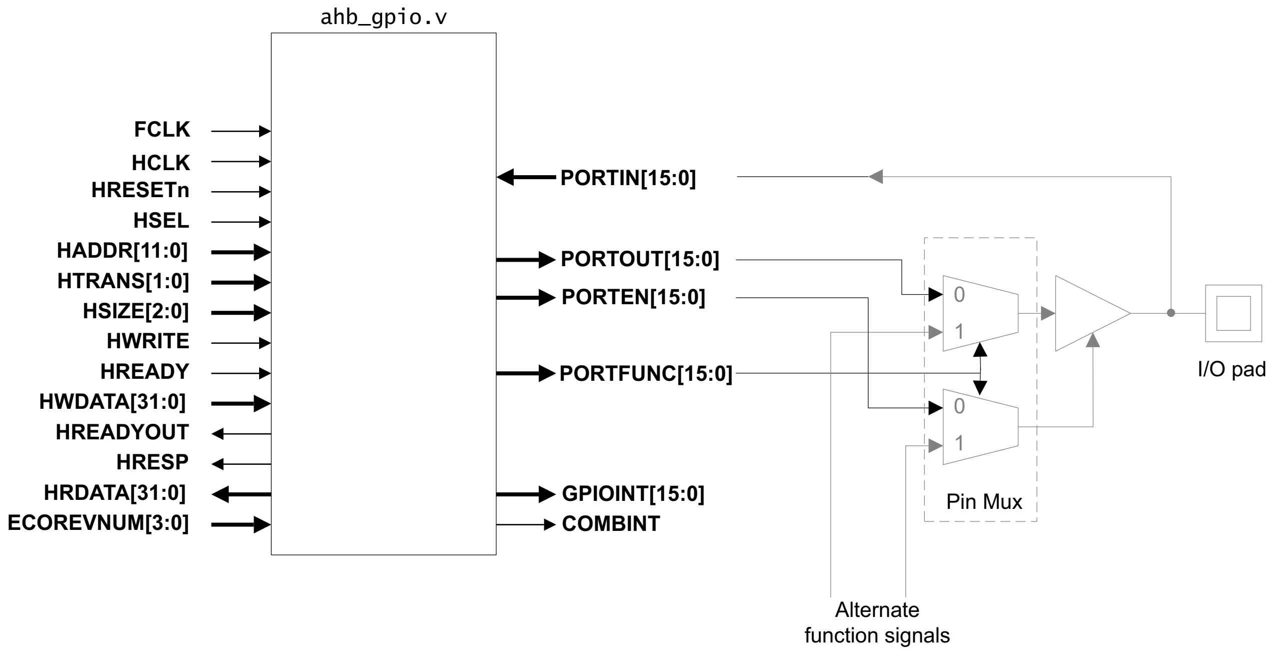


Figure 3-6 AHB GPIO control circuit and external interface

Table 3-6 shows the characteristics of the AHB GPIO.

Table 3-6 GPIO characteristics

Element name	Description
Filename	`ahb_gpio.v`

Parameters	The parameters are as follows:
	`ALTERNATE_FUNC_MASK`
	Indicates the pin that can have an alternate function. This parameter is set to `16'hFFFF` by default. This means that all 16 pins can have alternate functions.
	`ALTERNATE_FUNC_DEFAULT`
	Default value for alternate function setting. This parameter is set to `16'h0000` by default. This means that all pins are used for the GPIO function after reset.
	`BE` Big-endian. The default value is 0, little-endian. Set the value to 1 for big-endian configuration.

3.5.1 Features of the GPIO

The following sections describe the features of the GPIO:

- *Interrupt generation*
- *Masked access*.

Interrupt generation

The AHB GPIO provides programmable interrupt generation features. Three registers control this, and each register has separate set and clear addresses. You can configure each bit of the I/O pins to generate interrupts based on these three registers. See Table 3-7.

Table 3-7 Interrupt generation

Interrupt enable[n]	Interrupt polarity[n]	Interrupt type[n]	Interrupt feature
0	-	-	Disabled
1	0	0	Low-level
1	0	1	Falling edge
1	1	0	High-level
1	1	1	Rising edge

After an interrupt is triggered, the corresponding bit in the INTSTATUS Register is set. This also causes the corresponding bit of the **GPIOINT[15:0]** signal to be asserted. As a result, the combined interrupt signal, **COMBINT**, is also asserted. You can clear the interrupt status using an interrupt handler that writes 1 to the corresponding bit of the INTCLEAR Register, the same address as the INTSTATUS Register.

Note

The free running clock signal, **FCLK** must be active during interrupt detection, because of the double flip-flop synchronization logic. There is also a three cycle latency for the interrupt generation that is two cycles for input signal synchronization, and one cycle for registering of the interrupt status.

Masked access

The masked access feature permits individual bits or multiple bits, to be read from or written to in a single transfer. This avoids software-based read-modify-write operations that are not thread safe. With the masked access operations, the 16 bits I/O is divided into two halves, lower byte and the upper byte. The bit mask address spaces are defined as two arrays, each containing 256 words.

For example, if you must set bits[1:0] both to 1, and clear bits [7:6] in a single operation, you can carry out the write to the lower byte mask access address space. The required bit mask is `0xC3`, and you can write the operation as `MASKLOWBYTE[0xC3] = 0x03` as Figure 3-7 on page 3-13 shows.

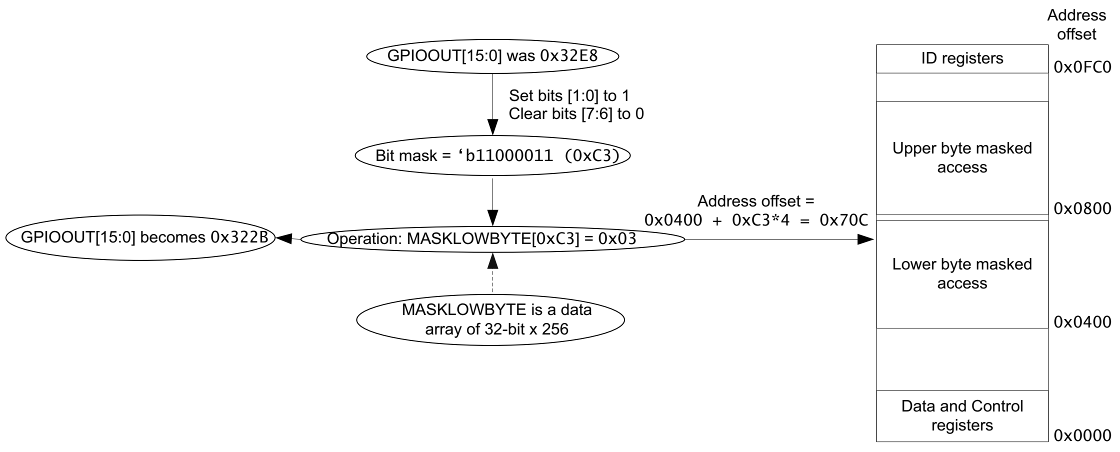

GPIOOUT[15:0] was 0x32E8
Set bits [1:0] to 1
Clear bits [7:6] to 0
Bit mask = 'b11000011 (0xC3)
Operation: MASKLOWBYTE[0xC3] = 0x03
GPIOOUT[15:0] becomes 0x322B
MASKLOWBYTE is a data array of 32-bit x 256
Address offset = 0x0400 + 0xC3*4 = 0x70C
Address offset
ID registers
0x0FC0
Upper byte masked access
0x0800
Lower byte masked access
0x0400
Data and Control registers
0x0000

Figure 3-7 Masked access 1

Similarly, if you must update some of the bits in the upper eight bits of the GPIO port, you must use the MASKHIGHBYTE array as Figure 3-8 shows.

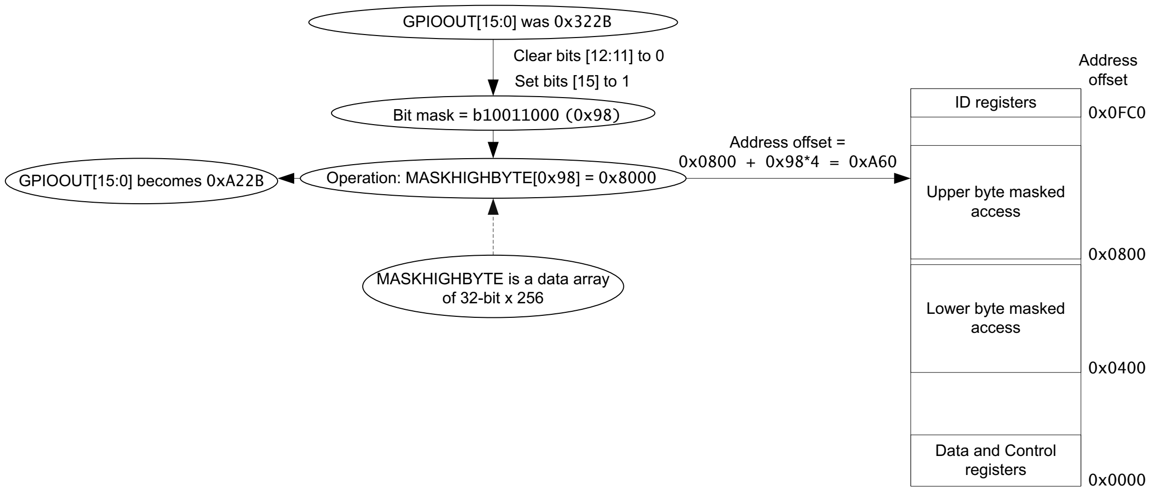

GPIOOUT[15:0] was 0x322B
Clear bits [12:11] to 0
Set bits [15] to 1
Bit mask = b10011000 (0x98)
Operation: MASKHIGHBYTE[0x98] = 0x8000
GPIOOUT[15:0] becomes 0xA22B
MASKHIGHBYTE is a data array of 32-bit x 256
Address offset = 0x0800 + 0x98*4 = 0xA60
Address offset
ID registers
0x0FC0
Upper byte masked access
0x0800
Lower byte masked access
0x0400
Data and Control registers
0x0000

Figure 3-8 Masked access 2

3.5.2 Programmers model

The example AHB GPIO contains the software programmable registers that Table 3-8 on page 3-14 shows.

Table 3-8 GPIO memory map

Name	Base offset	Type	Width	Reset value	Description
DATA	`0x0000`	R/W	16	`0x----`	Data value [15:0]: **Read** Sampled at pin. **Write** To data output register. Read back value is going through double flip-flop synchronization logic with a delay of two cycles.
DATAOUT	`0x0004`	R/W	16	`0x0000`	Data output Register value [15:0]: **Read** Current value of data output register. **Write** To data output register.
Reserved	`0x0008-0x000C`	-	-	-	Reserved
OUTENSET	`0x0010`	R/W	16	`0x0000`	Output enable set [15:0]: **Write** **1** Set the output enable bit. **0** No effect. **Read back** **0** Indicate the signal direction as input. **1** Indicate the signal direction as output.
OUTENCLR	`0x0014`	R/W	16	`0x0000`	Output enable clear [15:0]: **Write** **1** Clear the output enable bit. **0** No effect. **Read back** **0** Indicate the signal direction as input. **1** Indicate the signal direction as output.
ALTFUNCSET	`0x0018`	R/W	16	`0x0000`	Alternative function set [15:0]: **Write** **1** Set the ALTFUNC bit. **0** No effect. **Read back** **0** For I/O. **1** For an alternate function.
ALTFUNCCLR	`0x001C`	R/W	16	`0x0000`	Alternative function clear [15:0]: **Write** **1** Clear the ALTFUNC bit. **0** No effect. **Read back** **0** For I/O. **1** For an alternate function.
INTENSET	`0x0020`	R/W	16	`0x0000`	Interrupt enable set [15:0]: **Write** **1** Set the enable bit. **0** No effect. **Read back** **0** Interrupt disabled. **1** Interrupt enabled.

Table 3-8 GPIO memory map (continued)

Name	Base offset	Type	Width	Reset value	Description		
INTENCLR	`0x0024`	R/W	16	`0x0000`	Interrupt enable clear [15:0]:		
					Write	**1**	Clear the enable bit.
						0	No effect.
					Read back	**0**	Interrupt disabled.
						1	Interrupt enabled.
INTTYPESET	`0x0028`	R/W	16	`0x0000`	Interrupt type set [15:0]:		
					Write	**1**	Set the interrupt type bit.
						0	No effect.
					Read back	**0**	For LOW or HIGH level.
						1	For falling edge or rising edge.
INTTYPECLR	`0x002C`	R/W	16	`0x0000`	Interrupt type clear [15:0]:		
					Write	**1**	Clear the interrupt type bit.
						0	No effect.
					Read back	**0**	For LOW or HIGH level.
						1	For falling edge or rising edge.
INTPOLSET	`0x0030`	R/W	16	`0x0000`	Polarity-level, edge IRQ configuration [15:0]:		
					Write	**1**	Set the interrupt polarity bit.
						0	No effect.
					Read back	**0**	For LOW level or falling edge.
						1	For HIGH level or rising edge.
INTPOLCLR	`0x0034`	R/W	16	`0x0000`	Polarity-level, edge IRQ configuration [15:0]:		
					Write	**1**	Clear the interrupt polarity bit.
						0	No effect.
					Read back	**0**	For LOW level or falling edge.
						1	For HIGH level or rising edge.
INTSTATUS, INTCLEAR	`0x0038`	R/W	16	`0x0000`	Write one to clear interrupt request:		
					Write	[15:0] IRQ status clear Register. Write,	
						1	To clear the interrupt request.
						0	No effect.
					Read back	[15:0] IRQ status Register.	

Table 3-8 GPIO memory map (continued)

Name	Base offset	Type	Width	Reset value	Description
MASKLOWBYTE	`0x0400-0x07FC`	R/W	16	`0x----`	Lower eight bits masked access. Bits [9:2] of the address value are used as enable bit mask for the access: **[15:8]** Not used. Write is ignored, and read as 0. **[7:0]** Data for lower byte access, with [9:2] of address value use as enable mask for each bit.
MASKHIGHBYTE	`0x0800-0x0BFC`	R/W	16	`0x----`	Higher eight bits masked access. Bits [9:2] of the address value are used as enable bit mask for the access: **[15:8]** Data for higher byte access, with [9:2] of address value use as enable mask for each bit. **[7:0]** Not used. Write is ignored, and read as 0.
Reserved	`0x0C00 - 0x0FCF`	-	-	-	Reserved
PID4	`0x0FD0`	RO	8	`0x04`	Peripheral ID Register 4: **[7:4]** Block count. **[3:0]** jep106_c_code.
PID5[a]	`0x0FD4`	RO	-	`0x00`	Peripheral ID Register 5
PID6[a]	`0x0FD8`	RO	-	`0x00`	Peripheral ID Register 6
PID7[a]	`0x0FDC`	RO	-	`0x00`	Peripheral ID Register 7
PID0	`0x0FE0`	RO	8	`0x20`	Peripheral ID Register 0: **[7:0]** Part number[7:0].
PID1	`0x0FE4`	RO	8	`0xB8`	Peripheral ID Register 1: **[7:4]** jep106_id_3_0. **[3:0]** Part number[11:8].
PID2	`0x0FE8`	RO	8	`0x0B`	Peripheral ID Register 2: **[7:4]** Revision. **[3]** jedec_used. **[2:0]** jep106_id_6_4.
PID3	`0x0FEC`	RO	8	`0x00`	Peripheral ID Register 3: **[7:4]** ECO revision number. **[3:0]** Customer modification number.
CID0	`0x0FF0`	RO	8	`0x0D`	Component ID Register 0
CID1	`0x0FF4`	RO	8	`0xF0`	Component ID Register 1
CID2	`0x0FF8`	RO	8	`0x05`	Component ID Register 2
CID3	`0x0FFC`	RO	8	`0xB1`	Component ID Register 3

a. The PID 5, PID 6, and PID 7 registers are not used.

3.6 AHB to APB sync-down bridge

The AHB to APB sync-down bridge, `ahb_to_apb.v`, has the following features. Figure 3-9 shows the AHB to APB sync-down bridge:

- supports APB2, APB3, and APB4
- runs the APB interface synchronously slower than the AHB interface.

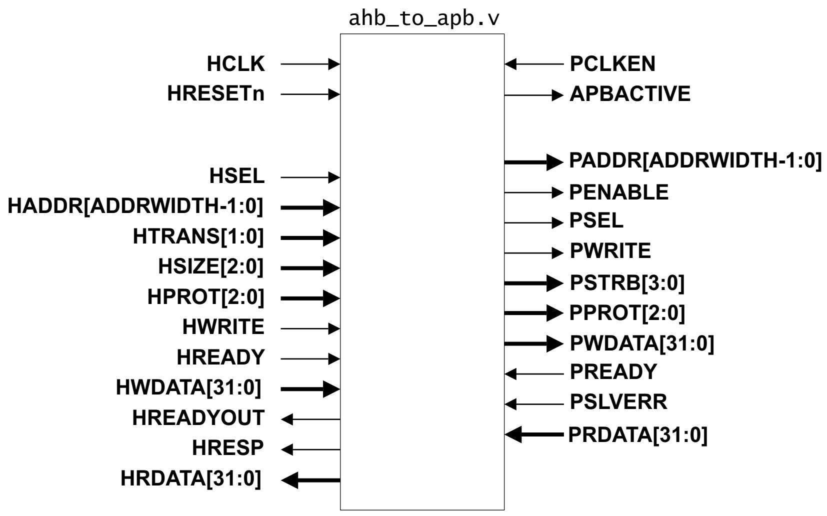


Figure 3-9 AHB to APB sync-down bridge

Table 3-9 shows the characteristics of the AHB to APB sync-down bridge module.

Table 3-9 AHB to APB sync-down bridge characteristics

Element name	Description		
Filename	`ahb_to_apb.v`		
Parameters	The parameters are as follows:		
	`ADDRWIDTH`	APB address width. The default value is 16, that is, 64K byte APB address space.	
	`REGISTER_RDATA`	**1**	Registered read data path.
		0	Combinational read data path.
		The default value is 1.	
Clock domain[a]	**HCLK**		

a. You can run APB at a clock divided from **HCLK** with **PCLKEN**.

The AHB to APB bridge has an output called **APBACTIVE** that controls the clock gating cell for generation of a gated **PCLK**. The gated **PCLK** is called **PCLKG** in the example system. When there is no APB transfer, this signal is LOW and stops **PCLKG**. The peripherals designed with separate clock pins for bus logic and peripheral operation can take advantage of the gated **PCLK** to reduce power consumption.

This block requires an APB clock synchronized to **HCLK**. **PCLK** can be divided or the same as **HCLK** by using **PCLKEN**.

When developing a system for AMBA 2.0, you can tie **PSLVERR** LOW, and **PREADY** HIGH.

When using the APB2 and APB3 peripheral systems, you can ignore the **PPROT[2:0]** and the **PSTRB[3:0]** signals.

For systems that do not require a high operating frequency, you can override the `REGISTER_RDATA` Verilog parameter to 0 to reduce the latency of APB accesses. This results in the read data from the APB slaves, **PRDATA**, being directly output to the AHB read data output, **HRDATA**, and it reduces the wait states in addition to the gate counts. By default, the `REGISTER_RDATA` parameter is set to 1 to include a registering stage.

For a system with **HCLK** equal to **PCLK**, and if there is no error response from APB slaves, the minimum number of cycles for each R/W are as follows:

- when `REGISTER_RDATA` is 1, there are 3 **HCLK** cycles
- when `REGISTER_RDATA` is 0, there are 2 **HCLK** cycles.

3.7 AHB to SRAM interface module

The AHB to SRAM interface module, `ahb_to_sram.v`, enables on-chip synchronous SRAM blocks to attach to an AHB interface. It performs read and write operations with zero wait states. The design supports 32 bits SRAM only. You can also use it in FPGA development for connecting FPGA block RAM to the AHB. Figure 3-10 shows the AHB to SRAM interface module.

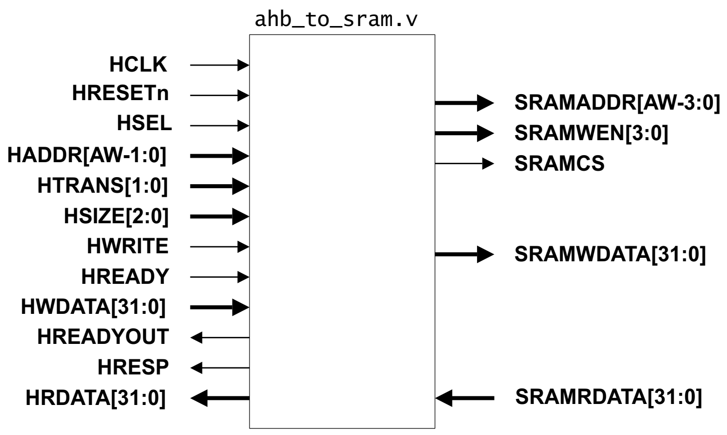


Figure 3-10 AHB to SRAM interface module

Table 3-10 shows the characteristics of the AHB to SRAM interface module.

Table 3-10 AHB to SRAM interface module characteristics

Element name	Description	
Filename	`ahb_to_sram.v`	
Parameters	`AW`	Address width. The default value is 16, that is, 64KB. For example, if the SRAM is 8KB, set AW to 13.
Clock domain	**HCLK**	

The design always responds with OKAY and zero wait states.

The AHB to SRAM interface module assumes the SRAM read and write access timings that Figure 3-11 on page 3-20 shows.

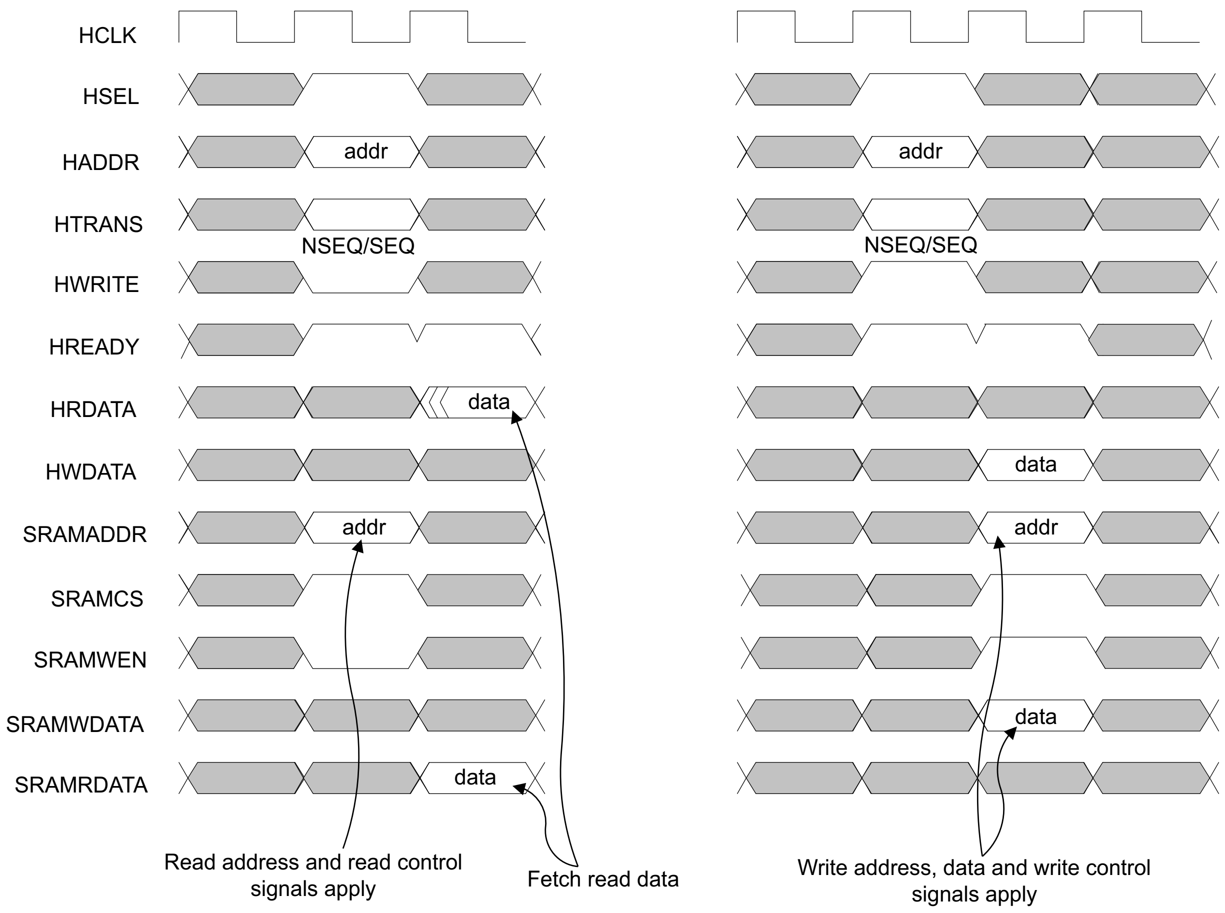


Figure 3-11 SRAM interface timing

If a read operation follows immediately after a write operation, the write address and write data are stored in an internal buffer, and the SRAM carries out the read operation first. The stalled write transfer is carried out when the AHB interface is idle, or when there is a write transfer.

A merging of read data between the internal buffers and the read data from SRAM is carried out automatically by the interface module, when:

- a read operation follows immediately after a write operation to the same address
- a sequence of read operations follows immediately after a write operation with any of the read transfers using the same address.

The merging processing uses internal buffer byte valid status and ensures the read data that returns to the bus master is up-to-date. This process occurs invisibly and does not result in any wait states.

3.8 AHB to flash interface module

The AHB to flash interface module, `ahb_to_flash32.v`, supports connection of a simple 32 bits read-only flash memory model to an AHB system. It includes parameterized wait state generation. Figure 3-12 shows the AHB to flash interface module.

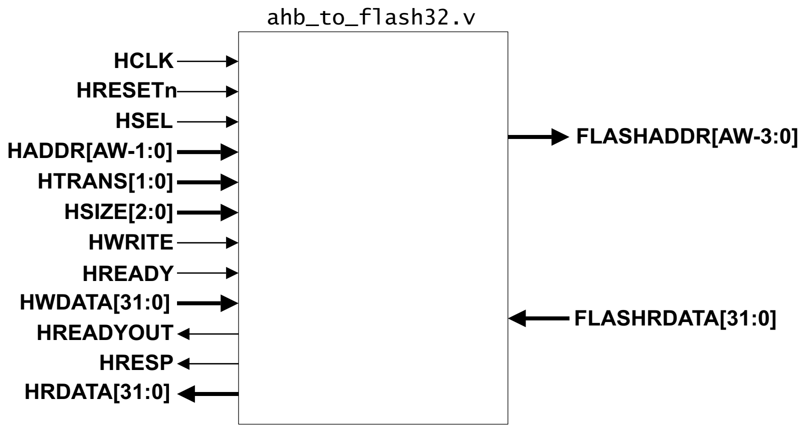


Figure 3-12 AHB to flash interface module

Table 3-11 shows the characteristics of the AHB to flash interface module.

Table 3-11 AHB to flash interface module characteristics

Element name	Description	
Filename	`ahb_to_flash32.v`	
Parameters	The parameters are as follows:	
	`AW`	Address width. The default value is 16.
	`WS`	Wait state. The default value is 1. The valid range of wait state is 0-3.
Clock domain	**HCLK**	

This interface module only supports read operations.

Figure 3-13 on page 3-22 shows the flash memory read access timings with different wait states.

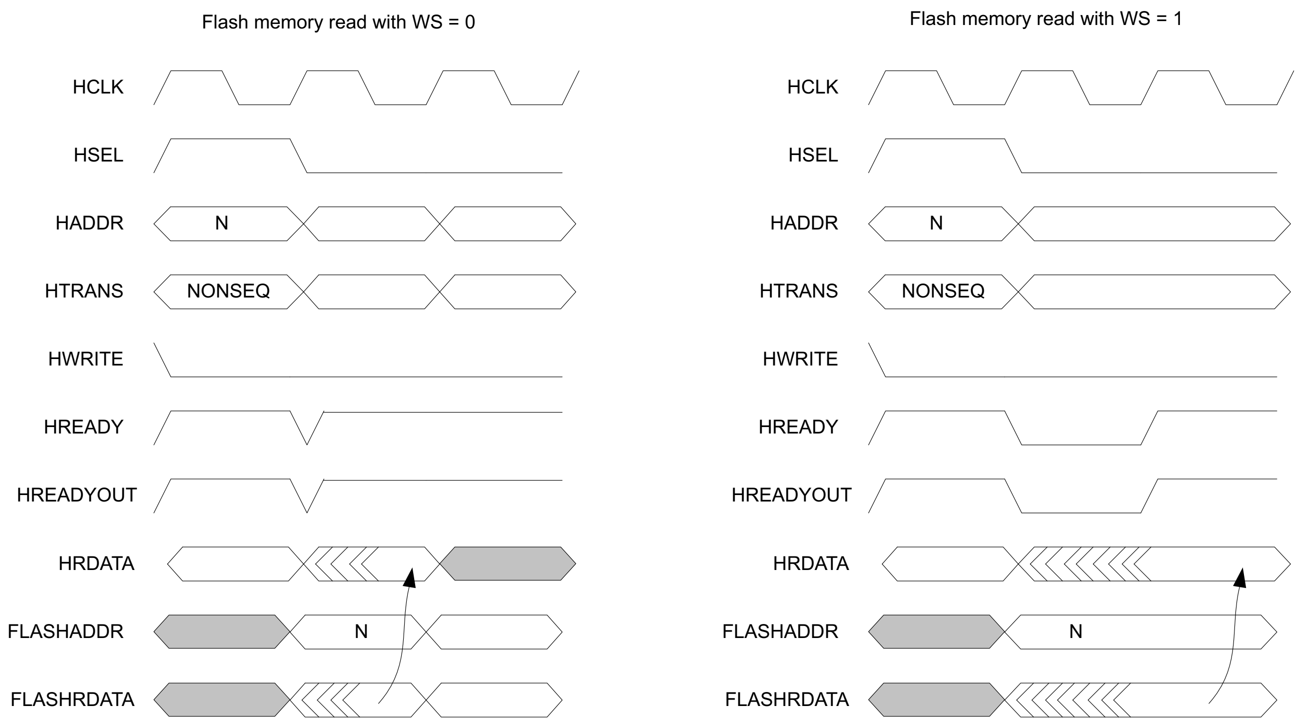


Figure 3-13 AHB to flash read access timing

3.9 AHB timeout monitor

The AHB timeout monitor, `ahb_timeout_monitor.v`, prevents an AHB slave from locking up a system. The AHB timeout monitor is placed between the AHB master and slave, and connected directly to the AHB slave. If there is an active transfer to the slave, and the slave holds **HREADY** LOW for more than a certain number of clock cycles, the monitor generates an error response to the bus master. Figure 3-14 shows the AHB timeout monitor module.

If the bus master generates any subsequent access to this slave, the monitor returns an error response, and blocks access to the slave until the slave has asserted its **HREADYOUT** HIGH.

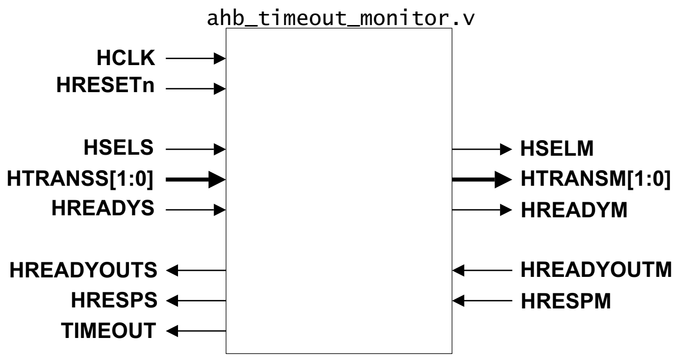


Figure 3-14 AHB timeout monitor

Figure 3-15 shows the typical usage of the AHB timeout monitor.

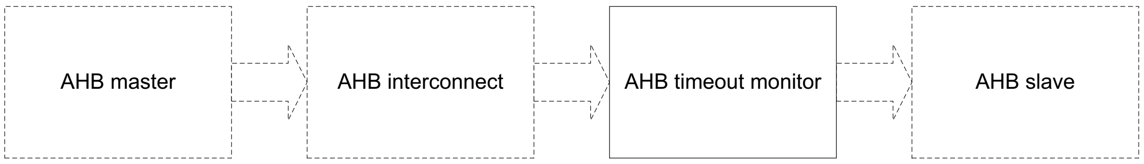


Figure 3-15 Use of AHB timeout monitor

If the monitor is directly coupled to the processor, or connected to an AHB path that is used for exception handler code access, the processor is not able to execute the bus fault exception handler.

If multiple bus slaves require monitoring, ARM recommends you use multiple monitors instead of putting one monitor at the AHB slave multiplexer connection, otherwise the monitor can block access to the program ROM or SRAM.

The `TIME_OUT_VAL` Verilog parameter determines the number of wait state cycles that trigger the timeout.

You can use the **TIMEOUT** output signal to export timeout events to external logic. During timeout, the **TIMEOUT** signal is asserted continuously until the AHB slave asserts the **HREADYOUT** signal.

Table 3-12 on page 3-24 shows the characteristics of the AHB timeout monitor.

Table 3-12 AHB timeout monitor characteristics

Element name	Description	
Filename	`ahb_timeout_monitor.v`	
Parameters	`TIME_OUT_VAL`	Number of wait cycles that trigger timeout. Permitted values for this parameter are 3-1024. The default value is 16.
Clock domain	**HCLK**	

3.10 AHB to external SRAM interface

The AHB to external SRAM interface module, `ahb_to_extmem16.v`, enables external SRAM, static memory devices or external peripherals, to connect to the Cortex-M processor design. The module supports only 16 bits and 8 bits external interfaces. Figure 3-16 shows the AHB to external SRAM interface module.

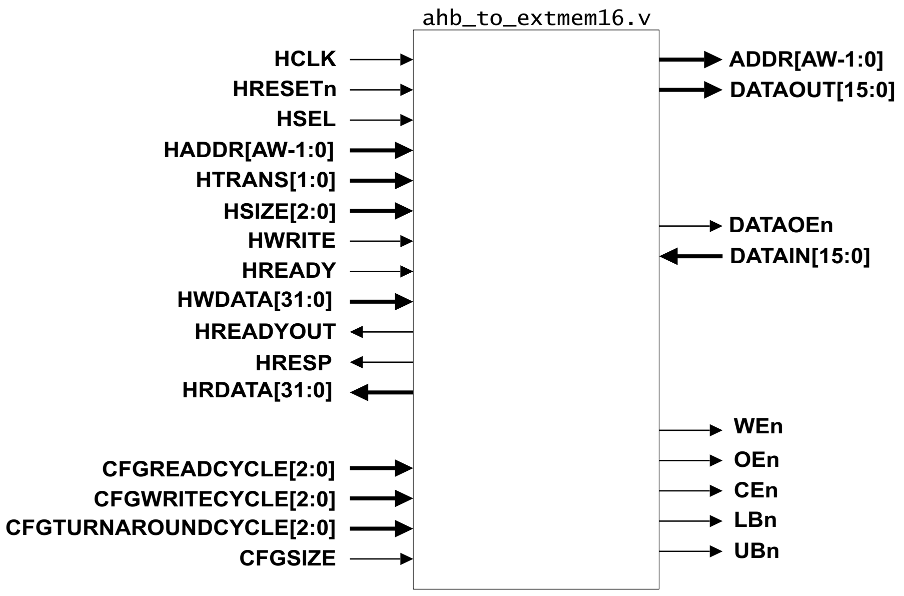


Figure 3-16 AHB to external SRAM interface

The interface module, `ahb_to_extmem16.v`, is designed to support an external bidirectional data bus. The **DATAOEn** signal controls the tristate buffer for data output. You must add your own tristate buffers in your system implementation. The design permits turnaround cycles to be inserted between reads and writes to prevent current spikes that could occur for a very short time when the processor system and the external device both drive the data bus. The following signals control wait states for reads, wait states for writes, and the number of turnaround cycles:

- **CFGREADCYCLE**
- **CFGWRITECYCLE**
- **CFGTURNAROUNDCYCLE**.

You can operate the interface module in 8 bits mode, with the **CFGSIZE** signal LOW, or 16 bits mode, with the **CFGSIZE** signal HIGH. All the configuration control signals must remain stable during operations. The design generates an OKAY response.

Table 3-13 shows the characteristics of the AHB to external SRAM interface.

Table 3-13 AHB to external SRAM interface characteristics

Element name	Description	
Filename	`ahb_to_extmem16.v`	
Parameters	`AW`	Address width.
Clock domain	**HCLK**	

3.10.1 Signal descriptions

Table 3-14 shows the non-AMBA signals that the AHB to external SRAM interface uses.

Table 3-14 AHB to external SRAM interface signals

Signal	Description
CFGREADCYCLE[2:0]	Number of clock cycles for a read operation. The value of 0 is equal to one read cycle, that is, 0 = one read cycle.
CFGWRITECYCLE[2:0]	Number of clock cycles for a write operation. The value of 0 is equal to one write cycle, that is, 0 = one write cycle. The interface module automatically inserts one additional setup cycle before the write and one hold cycle after the write.
CFGTURNAROUNDCYCLE[2:0]	Number of clock cycles required to switch between a read and a write operation on the tristate bus. The value of 0 is equal to one turnaround cycle, that is, 0 = one turnaround cycle.
CFGSIZE	Set: **LOW** For 8- bits memory. **HIGH** For 16 bits memory.
DATAOEn	Tristate buffer output enable for **DATAOUT**. Active LOW.
WEn	Write strobe for external memory device. Active LOW.
OEn	Read access output enable for external memory device. Active LOW.
CEn	Chip enable. Active LOW.
LBn	Lower byte enable. Active LOW.
UBn	Upper byte enable. Active LOW.

Figure 3-17 on page 3-27 shows the external SRAM interface timing for the following signals that are control wait states for reads, wait states for writes, and the number of turnaround cycles, respectively:

- **CFGREADCYCLE**=0
- **CFGWRITECYCLE**=0
- **CFGTURNAROUNDCYCLE**=0.

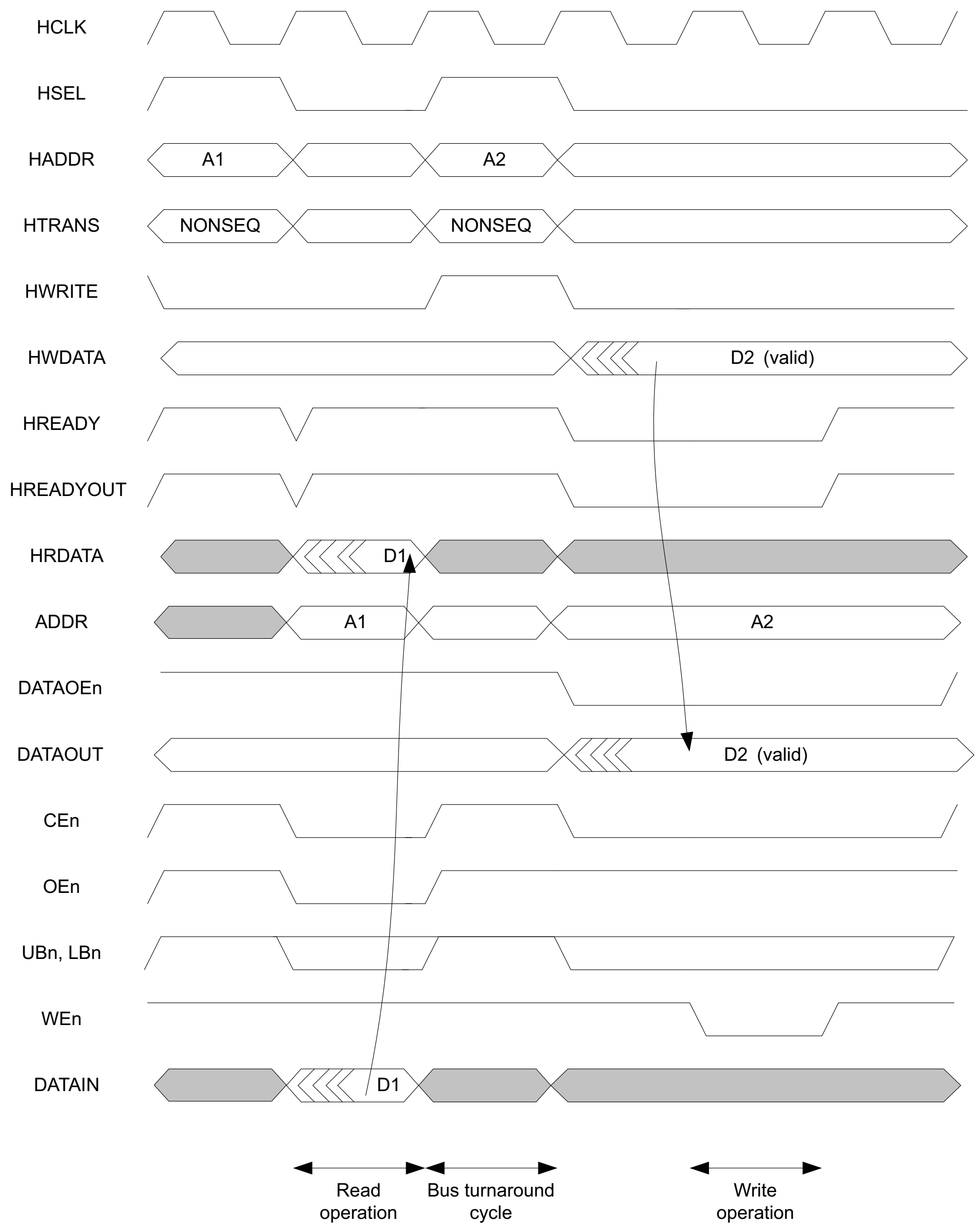


Figure 3-17 External SRAM interface timing 1

Figure 3-18 on page 3-28 shows the external SRAM interface timing for the following signals that are control wait states for reads, wait states for writes, and the number of turnaround cycles, respectively:

- **CFGREADCYCLE**=1, that is, two cycles
- **CFGWRITECYCLE**=1, that is, two cycles
- **CFGTURNAROUNDCYCLE**=1, that is, two cycles.

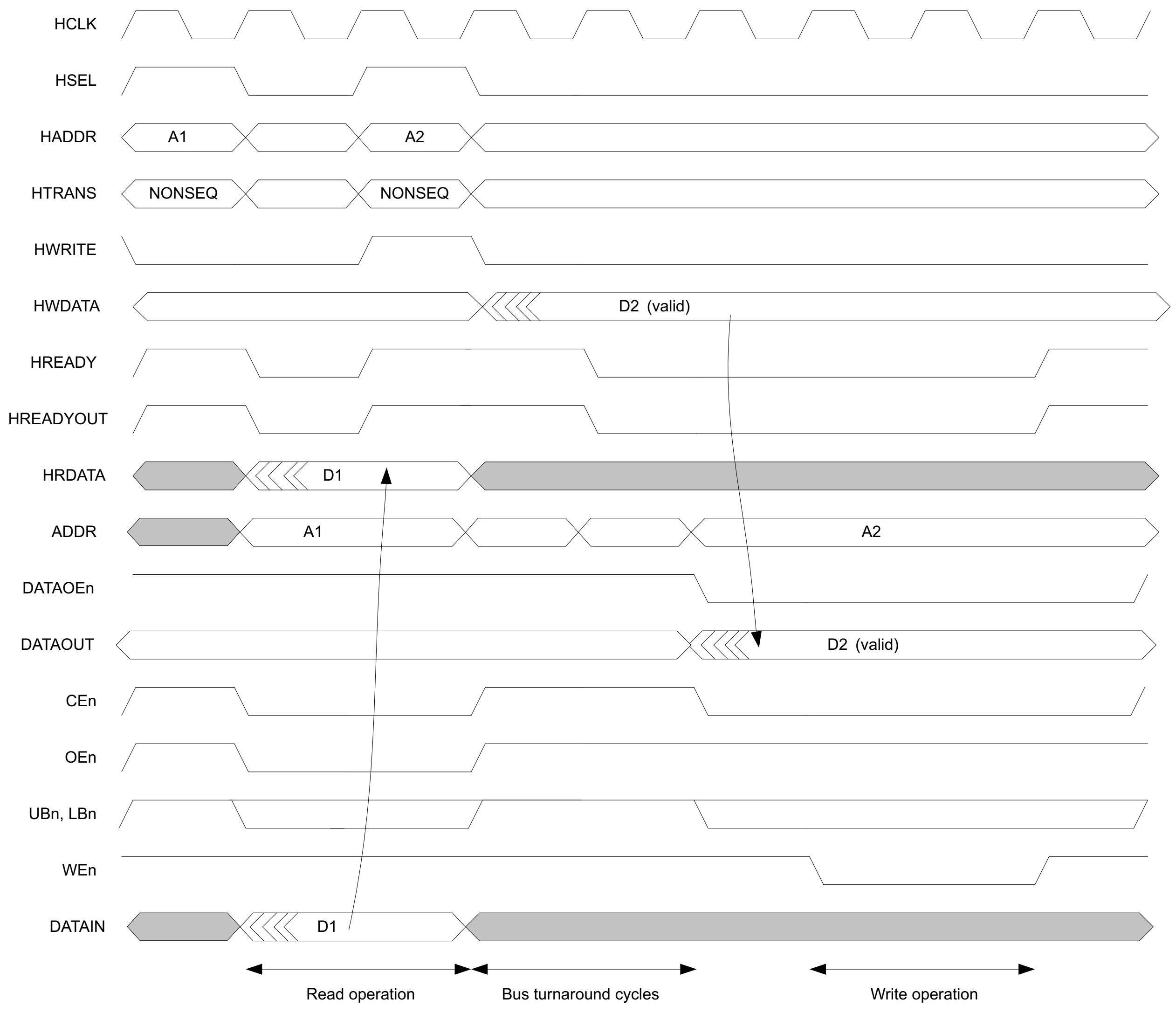


Figure 3-18 External SRAM interface timing 2

3.11 AHB bit-band wrapper for Cortex-M0 processor

The AHB bit-band wrapper, `ahb_bitband.v`, provides the bit-band functionality for the Cortex-M0 processor. Figure 3-19 shows the AHB bit-band wrapper module for the Cortex-M0 processor.

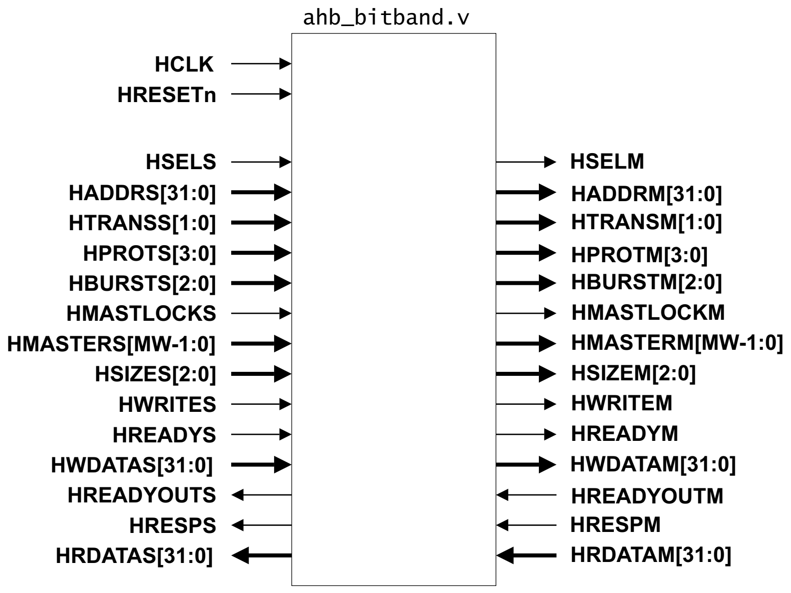


Figure 3-19 AHB bit-band wrapper for Cortex-M0 processor

Table 3-15 shows the characteristics of the AHB bit-band wrapper for the Cortex-M0 processor.

Table 3-15 AHB bit-band wrapper for Cortex-M0 processor characteristics

Element name	Description
Filename	`ahb_bitband.v`
Parameters	The parameters are as follows: `MW` Width of **HMASTER** signals. The default value is 1 because **HMASTER** in the Cortex-M0 processor has one bit. `BE` Big-endian. The default value is 0, little-endian. Set the value to 1 for big-endian configuration.
Clock domain	**HCLK**

When an AHB data transfer goes to bit band alias regions, `0x22000000` to `0x23FFFFFC` or `0x42000000` to `0x43FFFFFC`, the transfer is remapped to bit band regions, `0x20000000` to `0x200FFFFF`, or `0x40000000` to `0x400FFFFF`.

If the transfer is a read operation, a single remapped read transfer is produced, and the *Least Significant Bit* (LSB) of the read data indicates the bit value read. If the transfer is a write operation, the transfer is converted into a locked read-modify-write sequence.

The written bit is replaced by the LSB of the write data from the bus master, for example, the Cortex-M0 processor. During the read-modify sequence, the **HMASTLOCK** signal is asserted to ensure that the operation is atomic.

The value of **HADDR** must be word-aligned when accessing bit band alias. The transfer size is either in word, half word or byte. The size of the transfer to the AHB slaves matches the transfer size that the bus master uses.

For instruction transfers, indicated by 0 in **HPROT[0]** or transfers to other memory locations, the transfers are not altered.

3.11.1 Bit-banding

Bit-banding maps a complete word of memory onto a single bit in the bit-band region. For example, writing to one of the alias words sets or clears the corresponding bit in the bit-band region. This enables every individual bit in the bit-banding region to be directly accessible from a word-aligned address using a single LDR instruction. It also enables individual bits to be toggled without performing a read-modify-write sequence of instructions.

The bit-band wrapper supports two bit-band regions. These occupy the lowest 1MB of the SRAM, `0x20000000`, and peripheral memory, `0x40000000`, regions respectively. These bit-band regions map each word in an alias region of memory to a bit in a bit-band region of memory.

The bit-band wrapper contains logic that controls bit-band accesses as follows:

- it remaps bit-band alias addresses to the bit-band region
- for reads, it extracts the requested bit from the read byte, and returns this in the LSB of the read data returned to the core
- for writes, it converts the write to an atomic read-modify-write operation.

The memory map has two 32MB alias regions that map to two 1MB bit-band regions:

- accesses to the 32MB SRAM alias region map to the 1MB SRAM bit-band region
- accesses to the 32MB peripheral alias region map to the 1MB peripheral bit-band region.

A mapping formula shows how to reference each word in the alias region to a corresponding bit, or target bit, in the bit-band region. The mapping formula is:

```
bit_word_offset = (byte_offset x 32) + (bit_number x 4)
bit_word_addr = bit_band_base + bit_word_offset
```

where:

`bit_word_offset`	It is the position of the target bit in the bit-band memory region.
`bit_word_addr`	It is the address of the word in the alias memory region that maps to the targeted bit.
`bit_band_base`	It is the starting address of the alias region.
`byte_offset`	It is the number of the byte in the bit-band region that contains the targeted bit.
`bit_number`	It is the bit position, 0-7, of the targeted bit.

Figure 3-20 on page 3-31 shows examples of bit-band mapping between the SRAM bit-band alias region and the SRAM bit-band region:

- The alias word at `0x23FFFFE0` maps to bit [0] of the bit-band byte at `0x200FFFFF`: `0x23FFFFE0` = `0x22000000 + (0xFFFFF×32) + 0×4`.
- The alias word at `0x23FFFFFC` maps to bit [7] of the bit-band byte at `0x200FFFFF`: `0x23FFFFFC = 0x22000000 + (0xFFFFF×32) + 7×4`.
- The alias word at `0x22000000` maps to bit [0] of the bit-band byte at `0x20000000`: `0x22000000 = 0x22000000 + (0×32) + 0×4`.

- The alias word at `0x2200001C` maps to bit [7] of the bit-band byte at `0x20000000`: `0x2200001C = 0x22000000 + (0×32) + 7×4`.

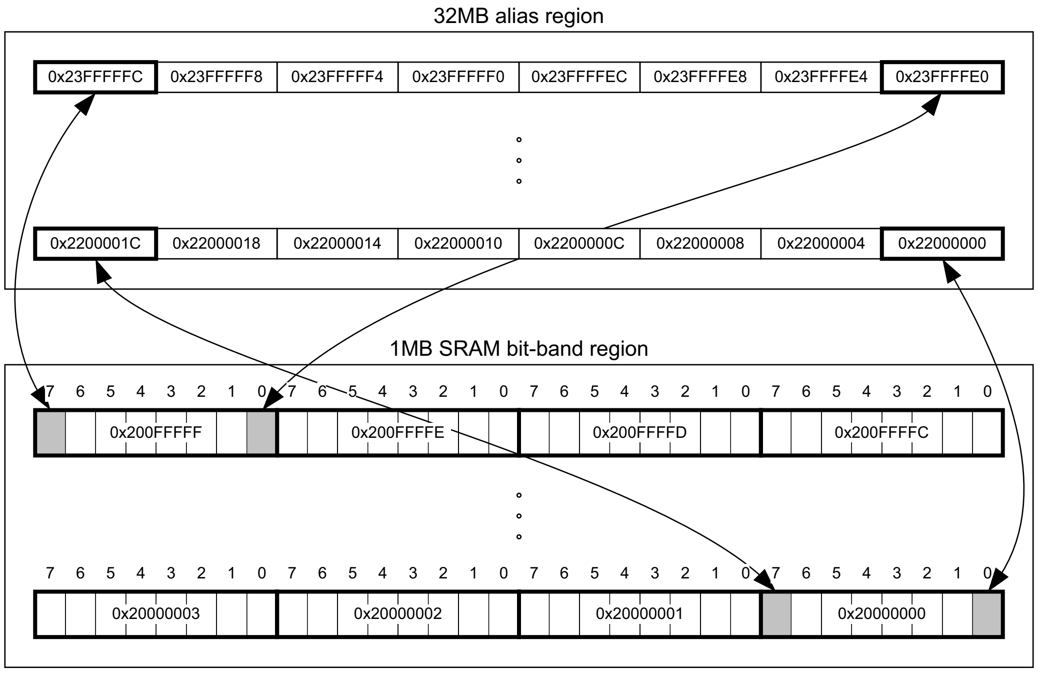


Figure 3-20 Bit-band mapping

Accessing an alias region directly

Writing to a word in the alias region has the same effect as a read-modify-write operation on the targeted bit in the bit-band region.

Bit [0] of the value written to a word in the alias region determines the value written to the targeted bit in the bit-band region. Writing a value with bit [0] set writes a 1 to the bit-band bit, and writing a value with bit [0] cleared writes a 0 to the bit-band bit.

Bits [31:1] of the alias word have no effect on the bit-band bit. Writing `0x01` has the same effect as writing `0xFF`. Writing `0x00` has the same effect as writing `0x0E`.

Reading a word in the alias region returns either `0x01` or `0x00`. A value of `0x01` indicates that the targeted bit in the bit-band region is set. A value of `0x00` indicates that the targeted bit is clear. Bits [31:1] are 0.

Directly accessing a bit-band region

You can directly access the bit-band region with normal reads and writes to that region.

Chapter 4
APB Components

This chapter describes the APB components that the Cortex-M System Design Kit uses. It contains the following sections:

4.1 Example APB slaves

The example APB slaves, `apb3_eg_slave.v` and `apb4_eg_slave.v`, demonstrate how to implement basic APB slaves. Each provides four words of hardware R/W registers and additional read-only ID registers. Each APB transfer to these example slaves takes two cycles, and no additional wait states are inserted. The following example slaves are included for the Cortex-M System Design Kit:

- APB3
- APB4.

Figure 4-1 shows an example APB3 slave module.

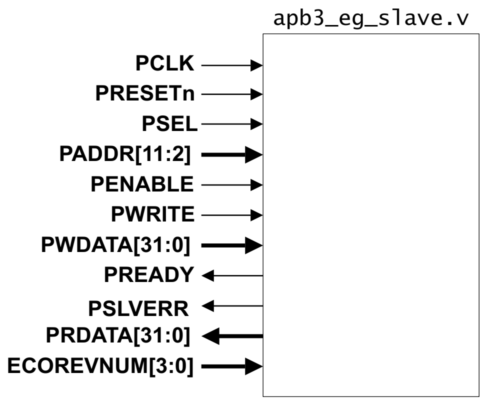


Figure 4-1 Example APB3 slave

Figure 4-2 shows an example APB4 slave module.

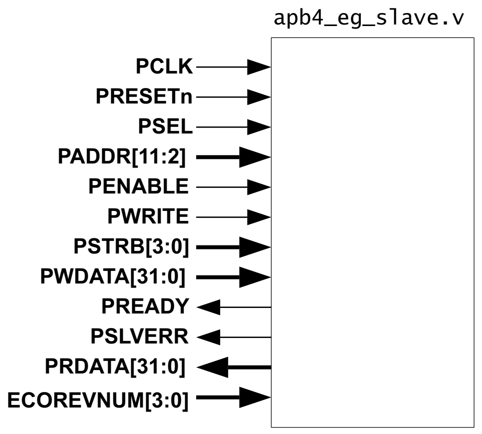


Figure 4-2 Example APB4 slave

The example APB slaves include the following features:

- A simple APB slave interface.
- 32 bits data bus, endian-independent. For the APB3 example slave, the data handling is 32 bits only. For the APB4 example slave, use the **PSTRB** signal to perform the write operations on individual bytes.
- Data transfers require two clock cycles.
- Four 32 bits R/W registers.

Table 4-1 shows the characteristics of the example APB slave.

Table 4-1 Example APB slave characteristics

Element name	Description	
Filename	`apb3_eg_slave.v`, for example APB3 slave. `apb4_eg_slave.v`, for example APB4 slave.	
Parameters	`ADDRWIDTH`	Width of the APB address bus. The default is 12.
Clock domain	**PCLK**	

Similar to the example AHB slave, the design of the APB example slaves are partitioned into an interface module and a register module. You can use the interface module to connect most peripheral blocks designed for traditional 8 bits or 16 bits microcontrollers to simplify migration to ARM-based systems.

4.1.1 Programmers model

Table 4-2 shows the example APB slave memory map.

Table 4-2 Example APB slave memory map

Name	Base offset	Type	Width	Reset value	Description
DATA0	`0x0000`	R/W	32	`0x00000000`	-
DATA1	`0x0004`	R/W	32	`0x00000000`	-
DATA2	`0x0008`	R/W	32	`0x00000000`	-
DATA3	`0x000C`	R/W	32	`0x00000000`	-
Unused	`0x0010` - `0x0FCF`	-	-	-	Read as 0 and write ignored
PID4	`0xFD0`	RO	8	`0x04`	Peripheral ID Register 4: **[7:4]** Block count. **[3:0]** jep106_c_code.
PID5	`0xFD4`	RO	8	`0x00`	Peripheral ID Register 5
PID6	`0xFD8`	RO	8	`0x00`	Peripheral ID Register 6
PID7	`0xFDC`	RO	8	`0x00`	Peripheral ID Register 7
PID0	`0xFE0`	RO	8	`0x18`	APB3 example slave. Peripheral ID Register 0: **[7:0]** Part number[7:0].
				`0x19`	APB4 example slave. Peripheral ID Register 0: **[7:0]** Part number[7:0].
PID1	`0xFE4`	RO	8	`0xB8`	Peripheral ID Register 1: **[7:4]** jep106_id_3_0. **[3:0]** Part number[11:8].
PID2	`0xFE8`	RO	8	`0x0B`	Peripheral ID Register 2: **[7:4]** Revision. **[3]** jedec_used. **[2:0]** jep106_id_6_4.

Table 4-2 Example APB slave memory map (continued)

Name	Base offset	Type	Width	Reset value	Description
PID3	`0xFEC`	RO	8	`0x00`	Peripheral ID Register 3: **[7:4]** ECO revision number. **[3:0]** Customer modification number.
CID0	`0xFF0`	RO	8	`0x0D`	Component ID Register 0
CID1	`0xFF4`	RO	8	`0xF0`	Component ID Register 1
CID2	`0xFF8`	RO	8	`0x05`	Component ID Register 2
CID3	`0xFFC`	RO	8	`0xB1`	Component ID Register 3

Note

The APB signal **PPROT[2:0]** is not required for the operations of the example APB slaves, therefore, these signals are not included in the design, and not shown in Figure 4-1 on page 4-2 and Figure 4-2 on page 4-2.

4.2 Timer

The APB timer, `apb_timer.v`, is a 32 bits down-counter with the following features:

- You can generate an interrupt request signal, **TIMERINT**, when the counter reaches 0. The interrupt request is held until it is cleared by writing to the INTCLEAR Register.
- You can use the zero to one transition of the external input signal, **EXTIN**, as a timer enable.
- If the APB timer count reaches 0, and at the same time, the software clears a previous interrupt status, then the interrupt status is set to 1.
- The external clock, **EXTIN**, must be slower than half of the peripheral clock because it is sampled by a double flip-flop and then goes through edge-detection logic when the external inputs act as a clock. See *Programmers model* on page 4-6.
- A separate clock pin, **PCLKG**, for the APB register read or write logic that permits the clock to peripheral register logic to stop when there is no APB activity.
- Component ID and a Peripheral ID Registers. These read-only ID registers are optional. You must modify the following in these registers:
  - — part number, 12 bits
  - — JEDEC ID value, 7 bits.
- The **ECOREVNUM** input signal is connected to the ECO revision number in the Peripheral ID Register 3.

Figure 4-3 shows the APB timer module.

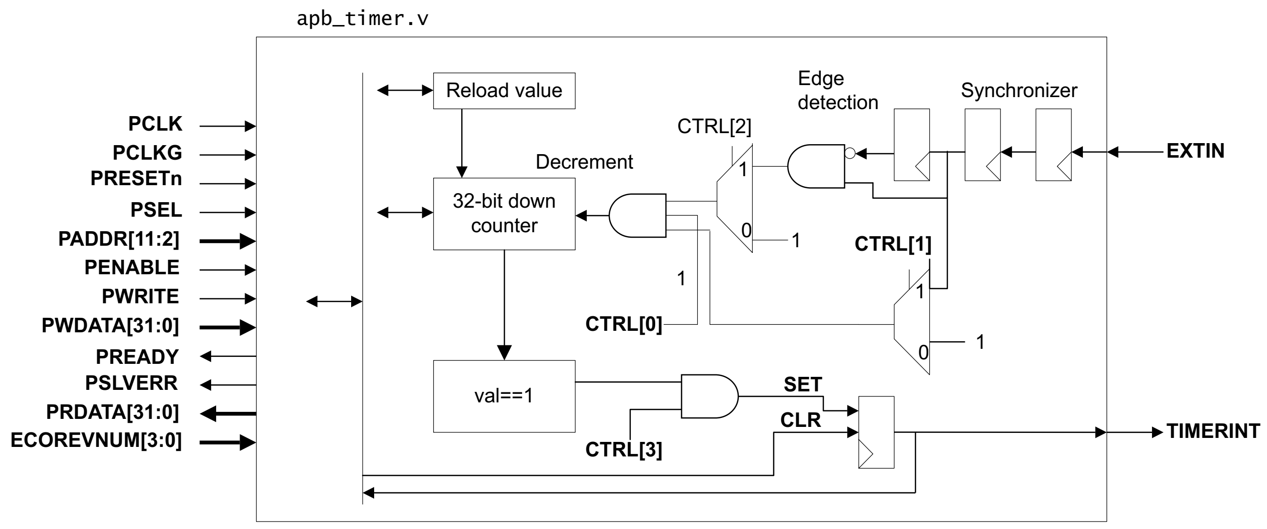


Figure 4-3 APB timer

Table 4-3 shows the characteristics of the APB timer.

Table 4-3 APB timer characteristics

Element name	Description
Filename	`apb_timer.v`.
Parameters	None.
Clock domain	You can turn-off the gated peripheral bus clock for register access, **PCLKG**, when there is no APB access. Free running clock, **PCLK**, for timer operation. This is the same frequency as, and synchronous to, the **PCLKG** signal.

4.2.1 Programmers model

Table 4-4 shows the APB timer memory map.

Table 4-4 APB timer memory map

Name	Base offset	Type	Width	Reset value	Description	
CTRL	`0x000`	R/W	4	`0x0`	**[3]**	Timer interrupt enable.
					[2]	Select external input as clock.
					[1]	Select external input as enable.
					[0]	Enable.
VALUE	`0x004`	R/W	32	`0x00000000`	**[31:0]**	Current value.
RELOAD	`0x008`	R/W	32	`0x00000000`	**[31:0]**	Reload value. A write to this register sets the current value.
INTSTATUS INTCLEAR	`0x00C`	R/W	1	`0x0`	**[0]**	Timer interrupt. Write one to clear.
PID4	`0xFD0`	RO	8	`0x04`	Peripheral ID Register 4:	
					[7:4]	Block count.
					[3:0]	jep106_c_code.
PID5	`0xFD4`	RO	8	`0x00`	Peripheral ID Register 5	
PID6	`0xFD8`	RO	8	`0x00`	Peripheral ID Register 6	
PID7	`0xFDC`	RO	8	`0x00`	Peripheral ID Register 7	
PID0	`0xFE0`	RO	8	`0x22`	Peripheral ID Register 0:	
					[7:0]	Part number[7:0].
PID1	`0xFE4`	RO	8	`0xB8`	Peripheral ID Register 1:	
					[7:4]	jep106_id_3_0.
					[3:0]	Part number[11:8].
PID2	`0xFE8`	RO	8	`0x0B`	Peripheral ID Register 2:	
					[7:4]	Revision.
					[3]	jedec_used.
					[2:0]	jep106_id_6_4.

Table 4-4 APB timer memory map (continued)

Name	Base offset	Type	Width	Reset value	Description
PID3	`0xFEC`	RO	8	`0x00`	Peripheral ID Register 3: **[7:4]** ECO revision number. **[3:0]** Customer modification number.
CID0	`0xFF0`	RO	8	`0x0D`	Component ID Register 0
CID1	`0xFF4`	RO	8	`0xF0`	Component ID Register 1
CID2	`0xFF8`	RO	8	`0x05`	Component ID Register 2
CID3	`0xFFC`	RO	8	`0xB1`	Component ID Register 3

——— **Note** ———

The APB interface always responds with an OKAY, with no wait states, and is two cycles per transfer so you can ignore the **PSLVERR** and **PREADY** outputs for APB2 applications.

4.2.2 Signal descriptions

Table 4-5 shows the signals for the APB timer.

Table 4-5 APB timer signals

Signal	Direction	Description
EXTIN	Input	External input. This signal is synchronized by double flip-flops before the time logic uses it.
TIMERINT	Output	Timer interrupt output.

4.3 UART

The APB UART, `apb_uart.v`, is a simple design that supports 8 bits communication without parity, and is fixed at one stop bit per configuration. Figure 4-4 shows the UART module.

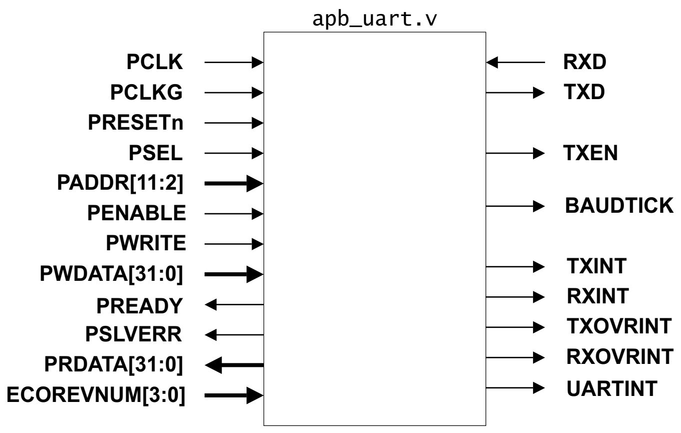


Figure 4-4 APB UART

The APB UART contains buffering. See Figure 4-5.

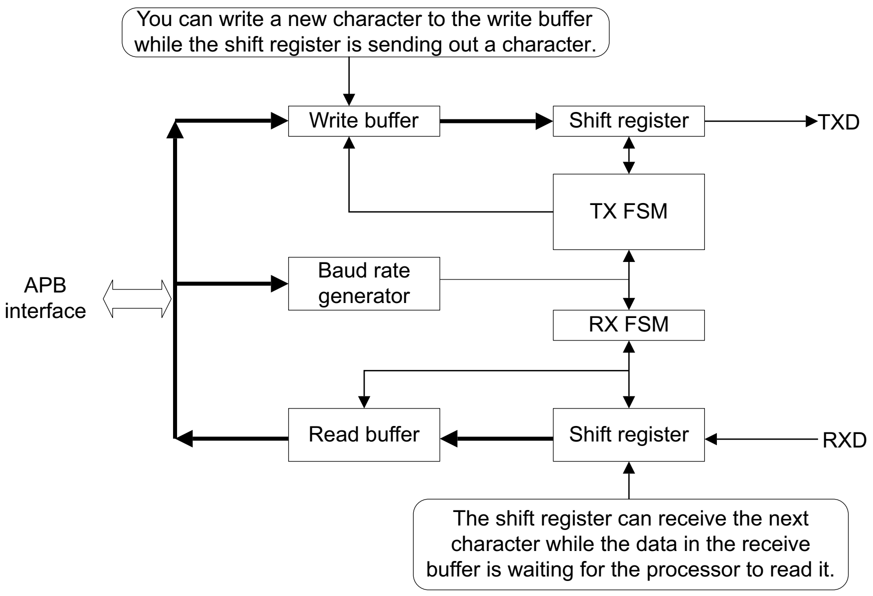

You can write a new character to the write buffer while the shift register is sending out a character.
Write buffer
Shift register
TXD
TX FSM
APB interface
Baud rate generator
RX FSM
Read buffer
Shift register
RXD
The shift register can receive the next character while the data in the receive buffer is waiting for the processor to read it.

Figure 4-5 APB UART buffering

This buffer arrangement is sufficient for most simple embedded applications. For example, a processor running at 30MHz with a baud rate of 115200 means a character transfer every 30e6×(1+8+1)/115200=2604 cycles. For duplex communication, the processor might receive an interrupt every 1300 clock cycles. Because the interrupt response time and the handler execution time are usually quite short, this leaves sufficient processing time for the thread.

Use double flip-flop synchronization to synchronize the receive data input.

Table 4-6 shows the characteristics of the APB UART.

Table 4-6 APB UART characteristics

Element name	Description
Filename	`apb_uart.v`
Parameters	None
Clock domain	**PCLKG** for register access. **PCLK** for timer operation. This is the same frequency as, and synchronous to, **PCLKG**.

4.3.1 Programmers model

Table 4-7 shows the example APB UART memory map.

Table 4-7 APB UART memory map

Name	Base offset	Type	Width	Reset value	Description	
DATA	`0x000`	R/W	8	`0x--`	**[7:0]**	Data value.
					Read	Received data.
					Write	Transmit data.
STATE	`0x004`	R/W	4	`0x0`	**[3]**	RX buffer overrun, write 1 to clear.
					[2]	TX buffer overrun, write 1 to clear.
					[1]	RX buffer full, read-only.
					[0]	TX buffer full, read-only.
CTRL	`0x008`	R/W	7	`0x00`	**[6]**	High-speed test mode for TX only.
					[5]	RX overrun interrupt enable.
					[4]	TX overrun interrupt enable.
					[3]	RX interrupt enable.
					[2]	TX interrupt enable.
					[1]	RX enable.
					[0]	TX enable.
INTSTATUS INTCLEAR	`0x00C`	R/W	4	`0x0`	**[3]**	RX overrun interrupt. Write 1 to clear.
					[2]	TX overrun interrupt. Write 1 to clear.
					[1]	RX interrupt. Write 1 to clear.
					[0]	TX interrupt. Write 1 to clear.
BAUDDIV	`0x010`	R/W	20	`0x00000`	**[19:0]**	Baud rate divider. The minimum number is 16.
PID4	`0xFD0`	RO	8	`0x04`	Peripheral ID 4 Register:	
					[7:4]	Block count.
					[3:0]	jep106_c_code.
PID5[a]	`0xFD4`	RO	8	`0x00`	Peripheral ID Register 5	
PID6[a]	`0xFD8`	RO	8	`0x00`	Peripheral ID Register 6	
PID7[a]	`0xFDC`	RO	8	`0x00`	Peripheral ID Register 7	
PID0	`0xFE0`	RO	8	`0x21`	Peripheral ID Register 0:	
					[7:0]	Part number[7:0].

Table 4-7 APB UART memory map (continued)

Name	Base offset	Type	Width	Reset value	Description
PID1	`0xFE4`	RO	8	`0xB8`	Peripheral ID Register 1: **[7:4]** jep106_id_3_0. **[3:0]** Part number[11:8].
PID2	`0xFE8`	RO	8	`0x0B`	Peripheral ID Register 2: **[7:4]** Revision. **[3]** jedec_used. **[2:0]** jep106_id_6_4.
PID3	`0xFEC`	RO	8	`0x00`	Peripheral ID Register 3: **[7:4]** ECO revision number. **[3:0]** customer modification number.
CID0	`0xFF0`	RO	8	`0x0D`	Component ID 0 Register
CID1	`0xFF4`	RO	8	`0xF0`	Component ID 1 Register
CID2	`0xFF8`	RO	8	`0x05`	Component ID 2 Register
CID3	`0xFFC`	RO	8	`0xB1`	Component ID 3 Register

a. The PID 5, PID 6, and PID 7 registers are not used.

The APB UART supports a high-speed test mode, useful for simulation during SoC or ASIC development. When **CTRL[6]** is set to 1, the serial data is transmitted at one bit per clock cycle. This enables you to send text messages in a much shorter simulation time. If required, you can remove this feature for silicon products to reduce the gate count. You can do this by removing bit 6 of the **reg_ctrl** signal in the verilog code. The APB interface always sends with an OKAY response with no wait state and is two cycles per transfer.

You must program the baud rate divider register before enabling the UART. For example, if the **PCLK** is running at 12MHz, and the required baud rate is 9600, then you must program the baud rate divider register as 12,000,000/9600 = 1250.

The **BAUDTICK** output pulses at a frequency of 16 times that of the programmed baud rate. You can use this signal for capturing UART data in a simulation environment.

The **TXEN** output signal indicates the status of **CTRL[0]**. You can use this signal to switch a bidirectional I/O pin in a silicon device to UART data output mode automatically when the UART transmission feature is enabled.

The buffer overrun status in the STATE field is used to drive the overrun interrupt signals. Therefore, clearing the buffer overrun status de-asserts the overrun interrupt, and clearing the overrun interrupt bit also clears the buffer overrun status bit in the STATE field.

4.4 Dual-input timers

The dual-input timers module, `apb_dualtimers.v`, is an APB slave module consists of two programmable 32 bits or 16 bits down-counters that can generate interrupts when they reach 0. You can program a timer to implement:

- a 32 bits or a 16 bits counter, and
- one of the following timer modes:
  - free-running
  - periodic
  - one-shot.

The operation of each timer module is identical. See *Functional description* for a functional description of each of the timer modes.

The dual-input timers module provides access to two interrupt-generating, programmable 32 bits *Free-Running Counters* (FRCs). The FRCs operate from a common timer clock, **TIMCLK**, and each FRC has its own clock enable input, **TIMCLKEN1** and **TIMCLKEN2**. Each FRC also has a prescaler that can divide down the enabled **TIMCLK** rate by 1, 16, or 256. This enables the count rate for each FRC, controlled independently using their individual clock enables and prescalers.

The system clock, **PCLK**, controls the programmable registers, and the second clock input drives the counter, enabling the counters to run from a much slower clock than the system clock. While register accesses are performed, the two clocks are synchronous. **TIMCLK** can be equal to or be a submultiple of the **PCLK** frequency. However, the positive edges of **TIMCLK** and **PCLK** must be synchronous.

Figure 4-6 shows a top-level block diagram of the timers.

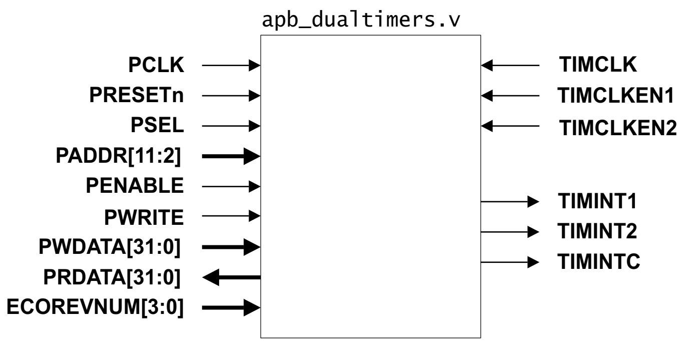


Figure 4-6 Dual-input timer components

4.4.1 Functional description

Two timers are defined by default, although you can easily expand this through extra instantiations of the FRC block. The same principle of simple expansion has been applied to the register configuration, to enable you to use more complex counters. For each timer, the following modes of operation are available:

Free-running mode

The counter wraps after reaching its zero value, and continues to count down from the maximum value. This is the default mode.

Periodic timer mode

The counter generates an interrupt at a constant interval, reloading the original value after wrapping past zero.

One-shot timer mode

The counter generates an interrupt once. When the counter reaches 0, it halts until you reprogram it. You can achieve this by either clearing the one-shot count bit in the control register, in which case the count proceeds according to the selection of Free-running or Periodic mode, or by writing a new value to the Load Value register.

4.4.2 Operation

Each timer has an identical set of registers as Table 4-8 on page 4-14 shows. The operation of each timer is identical. The timer is loaded by writing to the load register and, if enabled, counts down to 0. When a counter is already running, writing to the load register causes the counter to immediately restart at the new value. Writing to the background load value has no effect on the current count. The counter continues to decrement to 0, and then recommences from the new load value, if in periodic mode, and one-shot mode is not selected.

When 0 is reached, an interrupt is generated. You can clear the interrupt by writing to the clear register. If you selected one-shot mode, the counter halts when it reaches 0 until you deselect one-shot mode, or write a new load value.

Otherwise, after reaching a zero count, if the timer is operating in free-running mode, it continues to decrement from its maximum value. If you selected periodic timer mode, the timer reloads the count value from the Load Register and continues to decrement. In this mode, the counter effectively generates a periodic interrupt.

You select the mode using a bit in the Timer Control Register. See Table 4-9 on page 4-16. At any point, you can read the current counter value from the Current Value Register. You can enable the counter using a bit in the Control Register.

At reset, the counter is disabled, the interrupt is cleared, and the load register is set to 0. The mode and prescale values are set to free-running, and clock divide of one respectively. Figure 4-7 shows a block diagram of the free-running timer module.

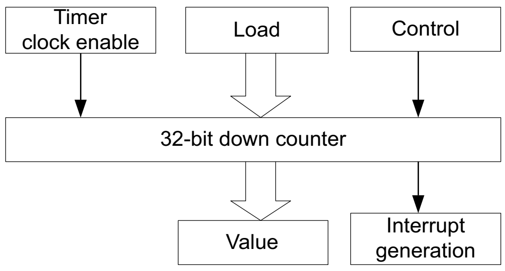


Figure 4-7 Free-running timer block

The timer clock enable is generated by a prescale unit. The counter then uses the enable to create a clock with one of the following timings:

- the system clock
- the system clock divided by 16, generated by 4 bits of prescale
- the system clock divided by 256, generated by a total of 8 bits of prescale.

Figure 4-8 on page 4-13 shows how the timer clock frequency is selected in the prescale unit. This enables you to clock the timer at different frequencies.

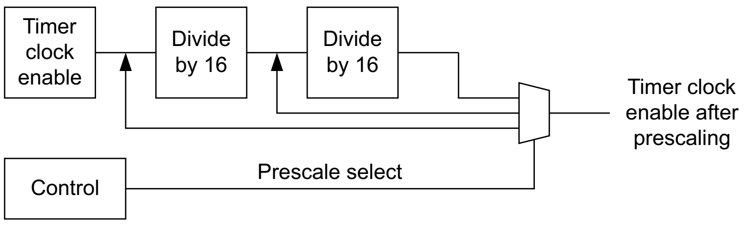


Figure 4-8 Prescale clock enable generation

Note

This selection is in addition to any similar facility already provided as part of any clock generation logic external to the timers.

Interrupt generation

An interrupt is generated when the full 32 bits counter reaches 0, and is only cleared when the TimerXClear location is written to. A register holds the value until the interrupt is cleared. The most significant carry bit of the counter detects the counter reaching 0.

You can mask interrupts by writing 0 to the Interrupt Enable bit in the Control Register. You can read the following from status registers:

- raw interrupt status, prior to masking
- final interrupt status, after masking.

The interrupts from the individual counters, after masking, are logically ORed into a combined interrupt, **TIMINTC**, and this provides an additional output from the timer peripheral.

4.4.3 Clocking

The timers contain the **PCLK** and **TIMCLK** clock inputs. **PCLK** is the main APB system clock, and the register interface uses it. **TIMCLK** is the input to the prescale units and the decrementing counters. You must qualify a pulse on **TIMCLK** by the appropriate **TIMCLKENx** signal being HIGH.

The design of the timers assumes that **PCLK** and **TIMCLK** are synchronous. To enable the counter to operate from a lower effective frequency than that at which **PCLK** is running, you can:

- connect both **PCLK** and **TIMCLK** inputs to the APB **PCLK** signal, and pulse **TIMCLKENx** HIGH at the required frequency, synchronized to **PCLK**
- tie **TIMCLKENx** HIGH and feed an enabled version of **PCLK** into the **TIMCLK** input. This provides sparse clock pulses synchronous to **PCLK**.

This provision of two clock inputs enables the counters to continue to run while the APB system is in a sleep state when **PCLK** is disabled. External system control logic must handle the changeover periods when **PCLK** is disabled and enabled to ensure that the **PCLK** and **TIMCLK** inputs are fed with synchronous signals when any register access is to occur.

4.4.4 Programmers model

Table 4-8 shows the timer registers.

Table 4-8 Timer memory map

Name	Base offset	Type	Width	Reset value	Description
TIMER1LOAD	`0x00`	R/W	32	`0x00000000`	See *Load Register* on page 4-15
TIMER1VALUE	`0x04`	RO	32	`0xFFFFFFFF`	See *Current Value Register* on page 4-15
TIMER1CONTROL	`0x08`	R/W	8	`0x20`	See *Timer Control Register* on page 4-15
TIMER1INTCLR	`0x0C`	WO	-	-	See *Interrupt Clear Register* on page 4-16
TIMER1RIS	`0x10`	RO	1	`0x0`	See *Raw Interrupt Status Register* on page 4-17
TIMER1MIS	`0x14`	RO	1	`0x0`	See *Interrupt Status Register* on page 4-17
TIMER1BGLOAD	`0x18`	R/W	32	`0x00000000`	See *Background Load Register* on page 4-17
TIMER2LOAD	`0x20`	R/W	32	`0x00000000`	See *Load Register* on page 4-15
TIMER2VALUE	`0x24`	RO	32	`0xFFFFFFFF`	See *Current Value Register* on page 4-15
TIMER2CONTROL	`0x28`	R/W	8	`0x20`	See *Timer Control Register* on page 4-15
TIMER2INTCLR	`0x2C`	WO	-	-	See *Interrupt Clear Register* on page 4-16
TIMER2RIS	`0x30`	RO	1	`0x0`	See *Raw Interrupt Status Register* on page 4-17
TIMER2MIS	`0x34`	RO	1	`0x0`	See *Interrupt Status Register* on page 4-17
TIMER2BGLOAD	`0x38`	R/W	32	`0x00000000`	See *Background Load Register* on page 4-17
TIMERITCR	`0xF00`	R/W	1	`0x0`	See *Integration Test Control Register* on page 4-18
TIMERITOP	`0xF04`	WO	2	`0x0`	See *Integration Test Output Set Register* on page 4-18
TIMERPERIPHID4	`0xFD0`	RO	8	`0x04`	Peripheral ID Register 4: **[7:4]** Block count. **[3:0]** jep106_c_code.
TIMERPERIPHID5[a]	`0xFD4`	RO	8	`0x00`	Peripheral ID Register 5
TIMERPERIPHID6[a]	`0xFD8`	RO	8	`0x00`	Peripheral ID Register 6
TIMERPERIPHID7[a]	`0xFDC`	RO	8	`0x00`	Peripheral ID Register 7
TIMERPERIPHID0	`0xFE0`	RO	8	`0x23`	Peripheral ID Register 0: **[7:0]** Part number[7:0].
TIMERPERIPHID1	`0xFE4`	RO	8	`0xB8`	Peripheral ID Register 1: **[7:4]** jep106_id_3_0. **[3:0]** Part number[11:8].
TIMERPERIPHID2	`0xFE8`	RO	8	`0x0B`	Peripheral ID Register 2: **[7:4]** Revision. **[3]** jedec_used. **[2:0]** jep106_id_6_4.

Table 4-8 Timer memory map (continued)

Name	Base offset	Type	Width	Reset value	Description
TIMERPERIPHID3	`0xFEC`	RO	8	`0x00`	Peripheral ID Register 3: **[7:4]** ECO revision number. **[3:0]** customer modification number.
TIMERPCELLID0	`0xFF0`	RO	8	`0x0D`	Component ID Register 0
TIMERPCELLID1	`0xFF4`	RO	8	`0xF0`	Component ID Register 1
TIMERPCELLID2	`0xFF8`	RO	8	`0x05`	Component ID Register 2
TIMERPCELLID3	`0xFFC`	RO	8	`0xB1`	Component ID Register 3

a. The TIMERPERIPHID5, TIMERPERIPHID6, and TIMERPERIPHID7 registers are not used.

Load Register

The TIMERXLOAD Register is a 32 bits register that contains the value from which the counter is to decrement. This is the value used to reload the counter when Periodic mode is enabled, and the current count reaches 0.

When this register is written to directly, the current count is immediately reset to the new value at the next rising edge of **TIMCLK** that **TIMCLKEN** enables.

The value in this register is also overwritten if the TIMERXBGLOAD Register is written to, but the current count is not immediately affected.

If values are written to both the TIMERXLOAD and TIMERXBGLOAD registers before an enabled rising edge on **TIMCLK**, the following occurs:

1. On the next enabled **TIMCLK** edge, the value written to the TIMERXLOAD value replaces the current count value.
2. Then, each time the counter reaches 0, the current count value is reset to the value written to TIMERXBGLOAD.

Reading from the TIMERXLOAD Register at any time after the two writes have occurred retrieves the value written to TIMERXBGLOAD. That is, the value read from TIMERXLOAD is always the value that takes effect for Periodic mode after the next time the counter reaches 0.

Current Value Register

The TIMERXVALUE Register provides the current value of the decrementing counter.

Timer Control Register

The TIMERXCONTROL Register is a read or write register. See Figure 4-9 on page 4-16.

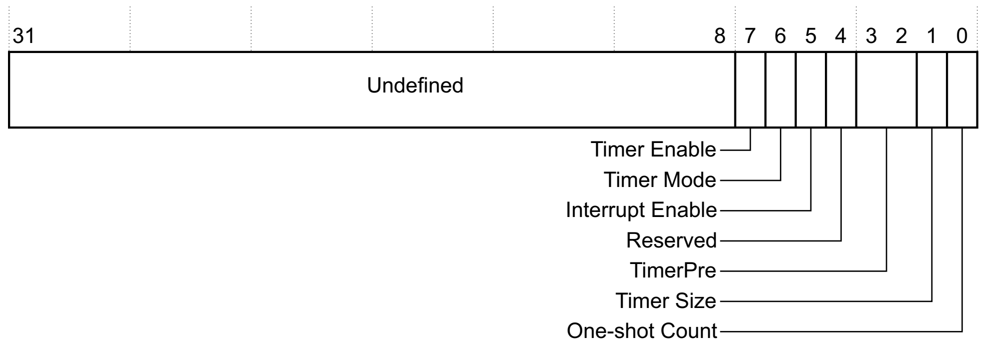


Figure 4-9 TIMERXCONTROL Register bit assignments

Table 4-9 shows the register bit assignments.

Table 4-9 TIMERXCONTROL Register bit assignments

Bits	Name	Function	
[31:8]	-	Reserved, read undefined, must read as 0s	
[7]	Timer Enable	Enable bit:	
		0	Timer disabled, default.
		1	Timer enabled.
[6]	Timer Mode	Mode bit:	
		0	Timer is in free-running mode, default.
		1	Timer is in periodic mode.
[5]	Interrupt Enable	Interrupt Enable bit:	
		0	Timer Interrupt disabled.
		1	Timer Interrupt enabled, default.
[4]	RESERVED	Reserved bit, do not modify, and ignore on read	
[3:2]	TimerPre	Prescale bits:	
		00	0 stages of prescale, clock is divided by 1, default.
		01	4 stages of prescale, clock is divided by 16.
		10	8 stages of prescale, clock is divided by 256.
		11	Undefined, do not use.
[1]	Timer Size	Selects 16 or 32 bits counter operation:	
		0	16 bits counter, default.
		1	32 bits counter.
[0]	One-shot Count	Selects one-shot or wrapping counter mode:	
		0	Wrapping mode, default.
		1	One-shot mode.

Interrupt Clear Register

Any write to the TIMERXINTCLR Register clears the interrupt output from the counter.

Raw Interrupt Status Register

This register is read-only. It indicates the raw interrupt status from the counter. This value is ANDed with the timer interrupt enable bit from the Timer Control Register to create the masked interrupt, that is passed to the interrupt output pin. See Figure 4-10.

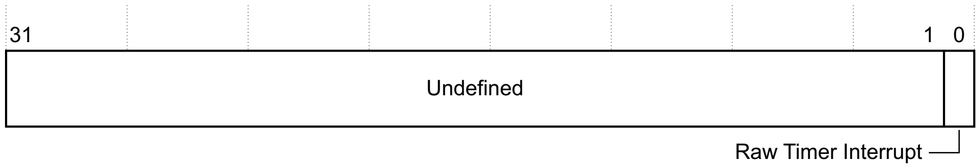


Figure 4-10 TIMERXRIS Register bit assignments

Table 4-10 shows the register bit assignments.

Table 4-10 TIMERXRIS Register bit assignments

Bits	Name	Function
[31:1]	-	Reserved, read undefined, must read as 0s
[0]	Raw Timer Interrupt	Raw interrupt status from the counter

Interrupt Status Register

The TIMERXMIS Register is read-only. It indicates the masked interrupt status from the counter. This value is the logical AND of the raw interrupt status with the timer interrupt enable bit from the Timer Control Register, and is the same value that is passed to the interrupt output pin. See Figure 4-11.

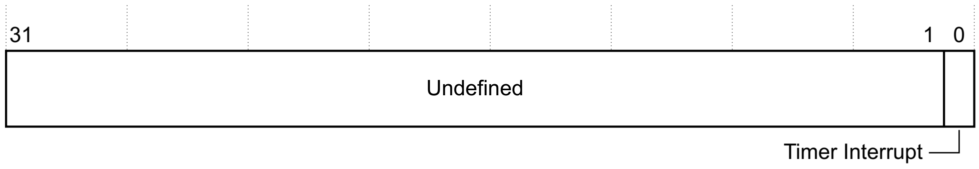


Figure 4-11 TIMERXMIS Register bit assignments

Table 4-11 shows the register bit assignments.

Table 4-11 TIMERXMIS Register bit assignments

Bits	Name	Function
[31:1]	-	Reserved, read as 0
[0]	Timer Interrupt	Enabled interrupt status from the counter

Background Load Register

The TIMERXBGLOAD Register is 32 bits and contains the value from which the counter is to decrement. This is the value used to reload the counter when Periodic mode is enabled, and the current count reaches 0.

This register provides an alternative method of accessing the TIMERXLOAD Register. The difference is that writes to TIMERXBGLOAD do not cause the counter to immediately restart from the new value.

Reading from this register returns the same value returned from TIMERXLOAD. See *Load Register* on page 4-15.

Integration Test Control Register

The TIMERITCR Register is R/W. It is a single-bit register that enables integration test mode. When in this mode, the Integration Test Output Set Register directly controls the masked interrupt outputs. The combined interrupt output, **TIMINTC**, then becomes the logical OR of the bits set in the Integration Test Output Set Register. See Figure 4-12.

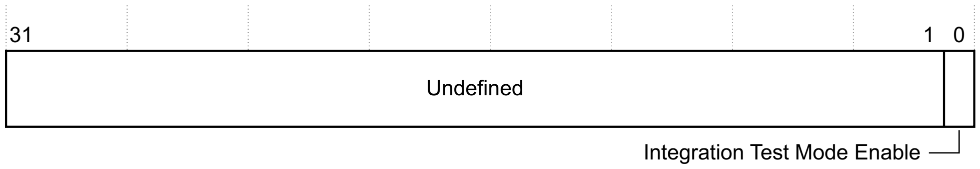


Figure 4-12 TIMERITCR Register bit assignments

Table 4-12 shows the register bit assignments.

Table 4-12 TIMERITCR Register bit assignments

Bits	Name	Function
[31:1]	-	Reserved, read as 0
[0]	Integration Test Mode Enable	When set HIGH, places the timers into integration test mode

Integration Test Output Set Register

When in integration test mode, the values in this write-only register, TIMERITOP, directly drive the enabled interrupt outputs. See Figure 4-13.

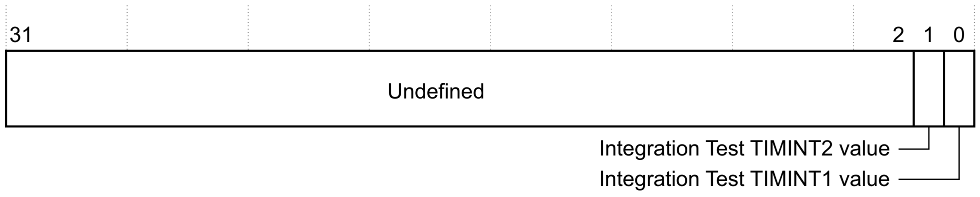

31
2
1
0
Undefined
Integration Test TIMINT2 value
Integration Test TIMINT1 value

Figure 4-13 TIMERITOP Register bit assignments

Table 4-13 shows the register bit assignments.

Table 4-13 TIMERITOP Register bit assignments

Bits	Name	Function
[31:2]	-	Reserved, read undefined, must read as 0s
[1]	Integration Test **TIMINT2** value	Value output on **TIMINT2** when in Integration Test Mode
[0]	Integration Test **TIMINT1** value	Value output on **TIMINT1** when in Integration Test Mode

4.4.5 Signal descriptions

Table 4-14 on page 4-19 shows the non-AMBA signals that the timer uses.

Table 4-14 Timer signals

Signal	Type	Direction	Description
TIMCLK	Timer clock	Input	The timer clock input. This must be synchronous to **PCLK** for normal operation.
TIMCLKEN1	Timer 1 clock enable	Input	The enable for the timer 1 clock input. The counter only decrements on a rising edge of **TIMCLK** when **TIMCLKEN1** is HIGH.
TIMCLKEN2	Timer 2 clock enable	Input	The enable for the timer 2 clock input. The counter only decrements on a rising edge of **TIMCLK** when **TIMCLKEN2** is HIGH.
TIMINT1	Counter 1 interrupt	Output	Active HIGH interrupt signal to the interrupt controller module. This signal indicates that counter 1 generated an interrupt having been decremented to 0.
TIMINT2	Counter 2 interrupt	Output	Active HIGH interrupt signal to the interrupt controller module. This signal indicates that counter 2 generated an interrupt having been decremented to 0.
TIMINTC	Combined counter interrupt	Output	Active HIGH interrupt signal to the interrupt controller module. This signal indicates that one of the counters generated an interrupt having been decremented to 0, and is the logical OR of **TIMINT1** and **TIMINT2**.
ECOREVNUM	ECO revision information	Input	It is connected to the ECO revision number in the Peripheral ID Register 3 to reflect revision changes during ECO of the chip design process. You can tie this signal LOW, or connect it to special tie-off cells so that you can change the ECO revision number at silicon netlists or a lower-level such as silicon mask.

4.5 Watchdog

The watchdog module is based on a 32 bits down-counter that is initialized from the Reload Register, WDOGLOAD. The watchdog module generates a regular interrupt, **WDOGINT**, depending on a programmed value. The counter decrements by one on each positive clock edge of **WDOGCLK** when the clock enable, **WDOGCLKEN**, is HIGH.

The watchdog monitors the interrupt and asserts a reset **WDOGRES** signal, when the counter reaches 0, and the counter is stopped. On the next enabled **WDOGCLK** clock edge, the counter is reloaded from the WDOGLOAD Register and the count-down sequence continues. If the interrupt is not cleared by the time that the counter next reaches 0, then the watchdog module reasserts the reset signal.

The watchdog module applies a reset to a system in the event of a software failure, providing a way to recover from software crashes. You can enable or disable the watchdog unit as required. Figure 4-14 shows watchdog module.

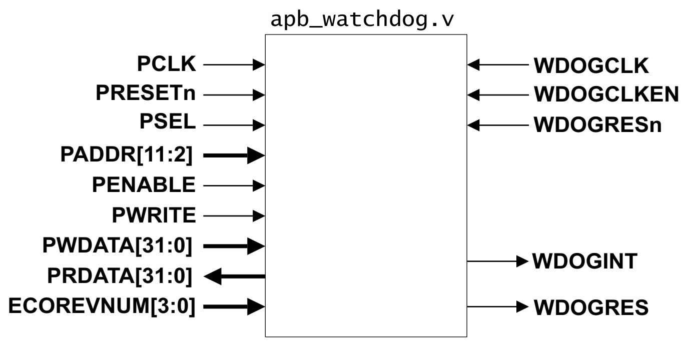


Figure 4-14 Watchdog components

Figure 4-15 shows the flow diagram for the watchdog operation.

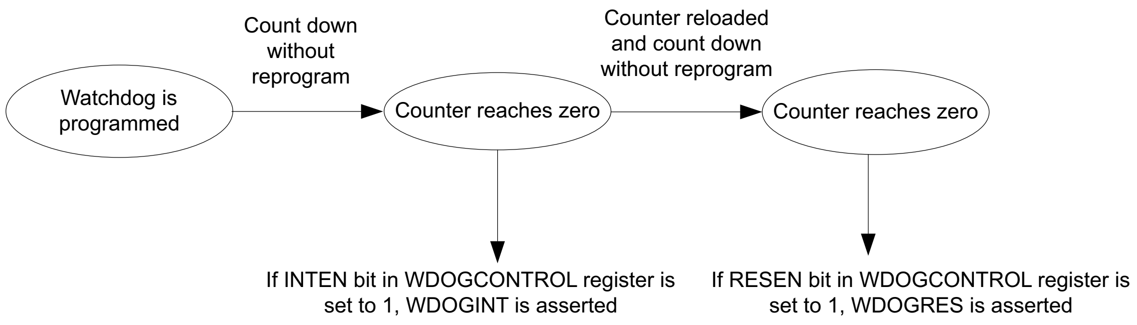

Watchdog is programmed
Count down without reprogram
Counter reaches zero
Counter reloaded and count down without reprogram
Counter reaches zero
If INTEN bit in WDOGCONTROL register is set to 1, WDOGINT is asserted
If RESEN bit in WDOGCONTROL register is set to 1, WDOGRES is asserted

Figure 4-15 Watchdog operation flow diagram

4.5.1 Programmers model

Table 4-15 shows the watchdog registers.

Table 4-15 Watchdog unit memory map

Name	Base offset	Type	Width	Reset value	Description
WDOGLOAD	`0x00`	R/W	32	`0xFFFFFFFF`	See *Watchdog Load Register* on page 4-22
WDOGVALUE	`0x04`	RO	32	`0xFFFFFFFF`	See *Watchdog Value Register* on page 4-22
WDOGCONTROL	`0x08`	R/W	2	`0x0`	See *Watchdog Control Register* on page 4-22
WDOGINTCLR	`0x0C`	WO	-	-	See *Watchdog Clear Interrupt Register* on page 4-23
WDOGRIS	`0x10`	RO	1	`0x0`	See *Watchdog Raw Interrupt Status Register* on page 4-23
WDOGMIS	`0x14`	RO	1	`0x0`	See *Watchdog Interrupt Status Register* on page 4-23
WDOGLOCK	`0xC00`	R/W	32	`0x0`	See *Watchdog Lock Register* on page 4-24
WDOGITCR	`0xF00`	R/W	1	`0x0`	See *Watchdog Integration Test Control Register* on page 4-24
WDOGITOP	`0xF04`	WO	2	`0x0`	See *Watchdog Integration Test Output Set Register* on page 4-25
WDOGPERIPHID4	`0xFD0`	RO	8	`0x04`	Peripheral ID Register 4: **[7:4]** Block count. **[3:0]** jep106_c_code.
WDOGPERIPHID5[a]	`0xFD4`	RO	8	`0x00`	Peripheral ID Register 5.
WDOGPERIPHID6[a]	`0xFD8`	RO	8	`0x00`	Peripheral ID Register 6.
WDOGPERIPHID7[a]	`0xFDC`	RO	8	`0x00`	Peripheral ID Register 7.
WDOGPERIPHID0	`0xFE0`	RO	8	`0x24`	Peripheral ID Register 0: **[7:0]** Part number[7:0].
WDOGPERIPHID1	`0xFE4`	RO	8	`0xB8`	Peripheral ID Register 1: **[7:4]** jep106_id_3_0. **[3:0]** Part number[11:8].
WDOGPERIPHID2	`0xFE8`	RO	8	`0x0B`	Peripheral ID Register 2: **[7:4]** Revision. **[3]** jedec_used. **[2:0]** jep106_id_6_4.
WDOGPERIPHID3	`0xFEC`	RO	8	`0x00`	Peripheral ID Register 3: **[7:4]** ECO revision number. **[3:0]** Customer modification number.
WDOGPCELLID0	`0xFF0`	RO	8	`0x0D`	Component ID Register 0.
WDOGPCELLID1	`0xFF4`	RO	8	`0xF0`	Component ID Register 1.
WDOGPCELLID2	`0xFF8`	RO	8	`0x05`	Component ID Register 2.
WDOGPCELLID3	`0xFFC`	RO	8	`0xB1`	Component ID Register 3.

a. The WDOGPERIPHID5, WDOGPERIPHID6, and WDOGPERIPHID7 registers are not used.

This section describes the functions implemented by the following registers:

- *Watchdog Load Register*
- *Watchdog Value Register*
- *Watchdog Control Register*
- *Watchdog Clear Interrupt Register* on page 4-23
- *Watchdog Raw Interrupt Status Register* on page 4-23
- *Watchdog Interrupt Status Register* on page 4-23
- *Watchdog Lock Register* on page 4-24
- *Watchdog Integration Test Control Register* on page 4-24
- *Watchdog Integration Test Output Set Register* on page 4-25.

Watchdog Load Register

The WDOGLOAD Register is a 32 bits register containing the value from which the counter is to decrement. When this register is written to, the count is immediately restarted from the new value. The minimum valid value for WDOGLOAD is 1.

Watchdog Value Register

The WDOGVALUE Register gives the current value of the decrementing counter.

Watchdog Control Register

The WDOGCONTROL Register is a R/W register that enables the software to control the watchdog unit. Figure 4-16 shows the WDOGCONTROL Register bit assignments.

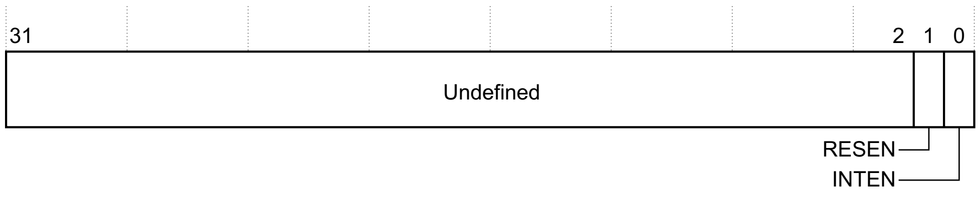


Figure 4-16 WDOGCONTROL Register bit assignments

Table 4-16 shows the register bit assignments.

Table 4-16 WDOGCONTROL Register bit assignments

Bits	Name	Function
[31:2]	-	Reserved, read undefined, must read as 0s.
[1]	RESEN	Enable watchdog reset output, **WDOGRES**. Acts as a mask for the reset output. Set HIGH to enable the reset, and LOW to disable the reset.
[0]	INTEN	Enable the interrupt event, **WDOGINT**. Set HIGH to enable the counter and the interrupt, and set LOW to disable the counter and interrupt. Reloads the counter from the value in WDOGLOAD when the interrupt is enabled, and was previously disabled.

Watchdog Clear Interrupt Register

A write of any value to the WDOGINTCLR Register clears the watchdog interrupt, and reloads the counter from the value in WDOGLOAD.

Watchdog Raw Interrupt Status Register

The WDOGRIS Register is read-only. It indicates the raw interrupt status from the counter. This value is ANDed with the interrupt enable bit from the control register to create the masked interrupt, that is passed to the interrupt output pin. See Figure 4-17.

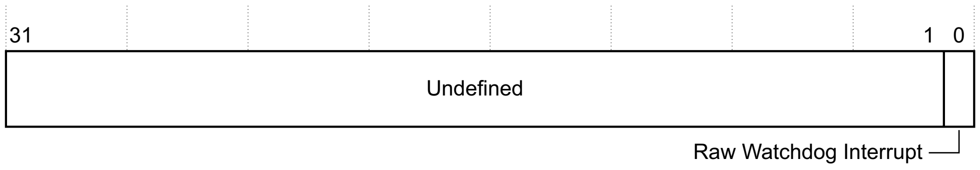


Figure 4-17 WDOGRIS Register bit assignments

Table 4-17 shows the register bit assignments.

Table 4-17 WDOGRIS Register bit assignments

Bits	Name	Function
[31:1]	-	Reserved, read undefined, must read as 0s
[0]	Raw Watchdog Interrupt	Raw interrupt status from the counter

Watchdog Interrupt Status Register

The WDOGMIS Register is read-only. It indicates the masked interrupt status from the counter. This value is the logical AND of the raw interrupt status with the INTEN bit from the control register, and is the same value that is passed to the interrupt output pin. See Figure 4-18.

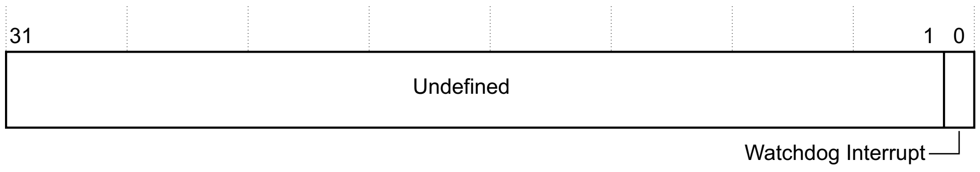


Figure 4-18 WDOGMIS Register bit assignments

Table 4-18 shows the register bit assignments.

Table 4-18 WDOGMIS Register bit assignments

Bits	Name	Function
[31:1]	-	Reserved, read undefined, must read as 0s
[0]	Watchdog Interrupt	Enabled interrupt status from the counter

Watchdog Lock Register

The WDOGLOCK Register is write-only. Using this register disables the write-accesses to all other registers. This is to prevent rogue software from disabling the watchdog functionality. Writing a value of `0x1ACCE551` enables write access to all other registers. Writing any other value disables write accesses. A read from this register returns only the bottom bit:

0	Indicates that write access is enabled, not locked.
1	Indicates that write access is disabled, locked.

Figure 4-19 shows the bit assignments for the WDOGLOCK Register.

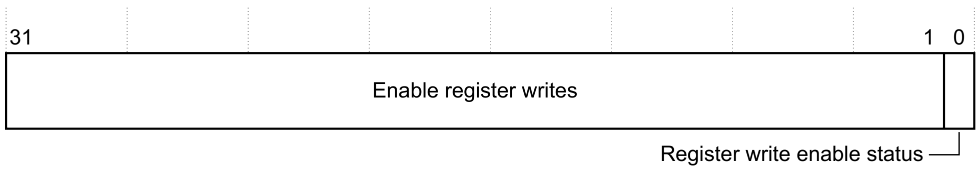


Figure 4-19 WDOGLOCK Register bit assignments

Table 4-19 shows the bit assignments for the WDOGLOCK Register.

Table 4-19 WDOGLOCK Register bit assignments

Bits	Name	Function
[31:1]	Enable register writes	Enable write access to all other registers by writing `0x1ACCE551`. Disable write access by writing any other value.
[0]	Register write enable status	**0** Write access to all other registers is enabled. This is the default. **1** Write access to all other registers is disabled.

Watchdog Integration Test Control Register

The WDOGITCR Register is R/W. It is a single-bit register that enables integration test mode. When in this mode, the test output register directly controls the masked interrupt output, **WDOGINT**, and reset output, **WDOGRES**. Figure 4-20 shows the bit assignments for the WDOGITCR Register.

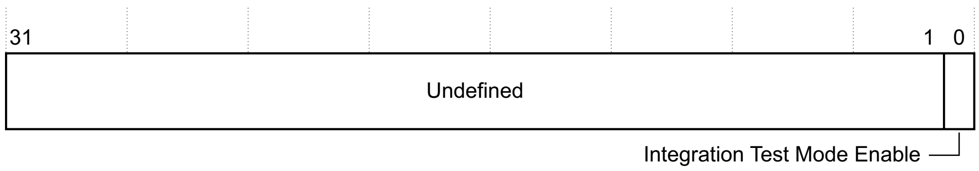


Figure 4-20 WDOGITCR Register bit assignments

Table 4-20 shows the WDOGITCR Register bit assignments.

Table 4-20 WDOGITCR Register bit assignments

Bits	Name	Function
[31:1]	-	Reserved, read undefined, must read as 0s
[0]	Integration Test Mode Enable	When set HIGH, places the watchdog into integration test mode

Watchdog Integration Test Output Set Register

The WDOGITOP Register is write-only. When in integration test mode, the values in this register directly drive the enabled interrupt output and reset output. Figure 4-21 shows the WDOGITOP Register bit assignments.

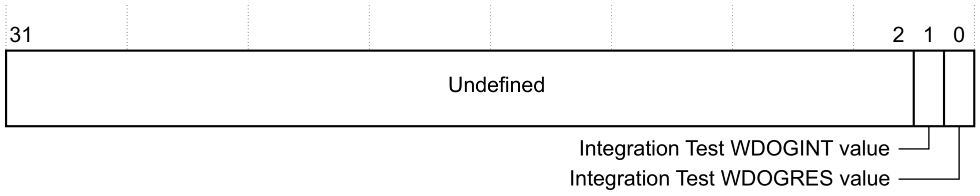

31
2
1
0
Undefined
Integration Test WDOGINT value
Integration Test WDOGRES value

Figure 4-21 WDOGITOP Register bit assignments

Table 4-21 shows the WDOGITOP Register bit assignments.

Table 4-21 WDOGITOP Register bit assignments

Bits	Name	Function
[31:2]	-	Reserved, read undefined, must read as 0s
[1]	Integration Test **WDOGINT** value	Value output on **WDOGINT** when in Integration Test Mode
[0]	Integration Test **WDOGRES** value	Value output on **WDOGRES** when in Integration Test Mode

4.5.2 Signal descriptions

Table 4-22 shows the non-AMBA signals that the watchdog unit uses.

Table 4-22 Watchdog unit signals

Signal	Type	Direction	Description
WDOGCLK	Watchdog clock	Input	The watchdog clock must be synchronous to the APB clock **PCLK**.
WDOGCLKEN	Watchdog clock enable	Input	The enable for the watchdog clock input. The counters only decrement on a rising edge of **WDOGCLK** when **WDOGCLKEN** is HIGH.
WDOGRESn	Watchdog reset	Input	The watchdog clock domain reset input.
WDOGINT	Watchdog interrupt	Output	The watchdog interrupt.
WDOGRES	Watchdog reset	Output	The watchdog timeout reset.
ECOREVNUM	ECO revision information	Input	It is connected to the ECO revision number in the Peripheral ID Register 3 to reflect revision changes during ECO of the chip design process. You can tie this signal LOW, or connect it to special tie-off cells so that you can change the ECO revision number at silicon netlists or a lower-level such as the silicon mask.

4.6 Slave multiplexer

The APB slave multiplexer, `apb_slave_mux.v`, supports up to 16 APB slaves. It uses four bits of **PADDR** to generate the **PSEL** and handle the data and response multiplexing. You can configure the four bits of **PADDR** that perform decoding, and you can drive them into **DECODE4BIT[3:0]**. The APB slave multiplexer supports various APB device footprints. Figure 4-22 shows the APB slave multiplexer module.

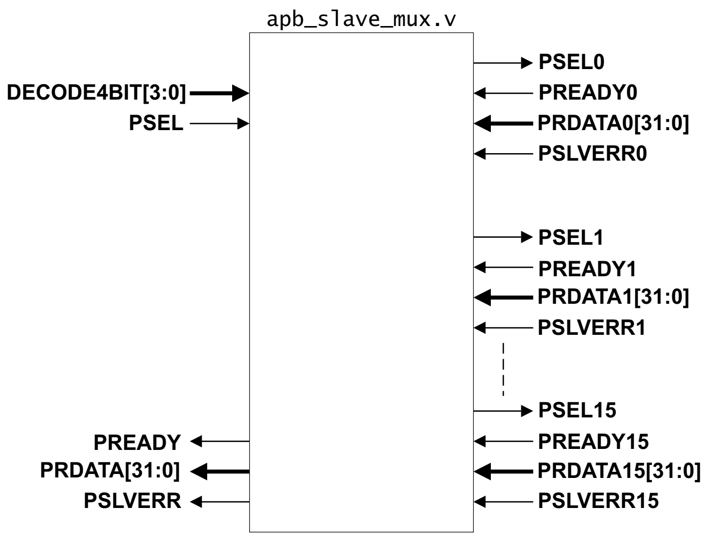


Figure 4-22 APB slave multiplexer

Table 4-23 shows the characteristics of the APB slave multiplexer.

Table 4-23 APB slave multiplexer characteristics

Element name	Description
Filename	`apb_slave_mux.v`
Parameters	The parameters are as follows: • `PORT0_ENABLE` to enable port 0 • `PORT1_ENABLE` to enable port 1 • `PORT2_ENABLE` to enable port 2 ... • `PORT15_ENABLE` to enable port 15. By default, all port enable parameters are set to 1, that is, enabled.
Clock domain	No clock input. Combinational logic only. Runs in the **PCLK** domain.

4.7 Subsystem

The APB subsystem, apb_subsystem.v, is a common platform for all example systems in the Cortex-M System Design Kit. It contains the APB timers, APB UART, dual-input timer, watchdog, AHB to APB bridge, a test slave, and IRQ synchronizers. Figure 4-23 shows the APB subsystem module.

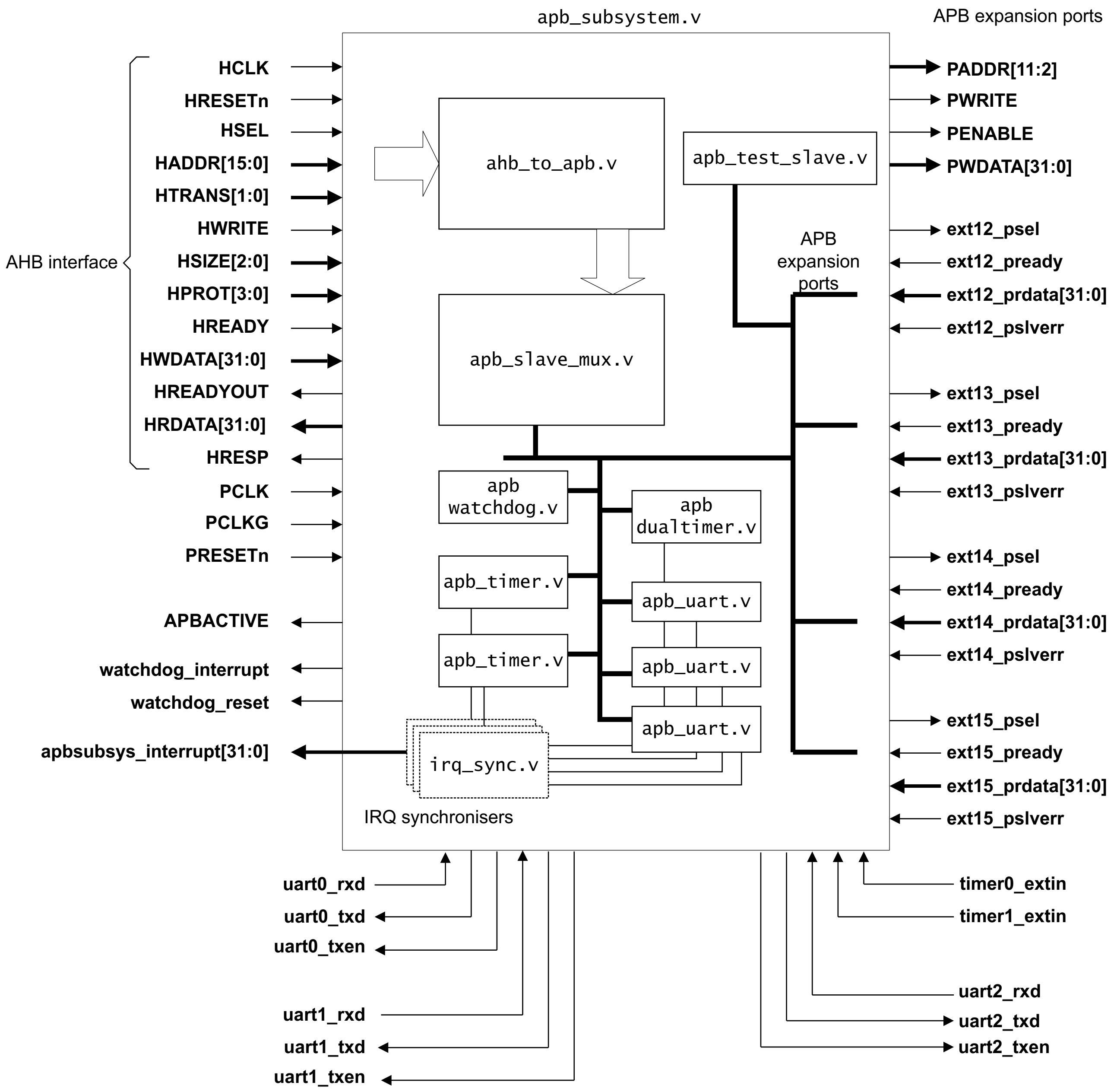


Figure 4-23 APB subsystem

Table 4-24 shows the characteristics of the APB subsystem.

Table 4-24 APB subsystem characteristics

Element name	Description
Filename	`apb_subsystem.v`
Parameter	The parameters are as follows: `APB_EXT_PORT12_ENABLE` Enable APB expansion port 12. `APB_EXT_PORT13_ENABLE` Enable APB expansion port 13. `APB_EXT_PORT14_ENABLE` Enable APB expansion port 14. `APB_EXT_PORT15_ENABLE` Enable APB expansion port 15. **Note** • ports 12-15 are APB3 slave ports • ports 0-11 are peripherals inside the APB subsystems. `INCLUDE_IRQ_SYNCHRONIZER` Set to 1 to include the IRQ synchronizer. Set to 0 to connect IRQ signals directly to the NVIC of the processor. The default value is 0. `INCLUDE_APB_TEST_SLAVE` Set to 1 to include `apb_test_slave`. Set to 0 to remove. The default value is 1. `INCLUDE_APB_TIMER0` Set to 1 to include timer #0. Set to 0 to remove. The default value is 1. `INCLUDE_APB_TIMER1` Set to 1 to include timer #1. Set to 0 to remove. The default value is 1. `INCLUDE_APB_DUALTIMER0` Set to 1 to include dual timer. Set to 0 to remove. The default value is 1. `INCLUDE_APB_UART0` Set to 1 to include uart #0. Set to 0 to remove. The default value is 1. `INCLUDE_APB_UART1` Set to 1 to include uart #1. Set to 0 to remove. The default value is 1. `INCLUDE_APB_UART2` Set to 1 to include uart #2. Set to 0 to remove. The default value is 1. `INCLUDE_APB_WATCHDOG` Set to 1 to include watchdog. Set to 0 to remove. The default value is 1. `BE` Big-endian. The default value is 0, little-endian. Set the value to 1 for big-endian configuration. **Note** By default, all port enable parameters are set to 0.
Clock domain	**HCLK** For the AHB to APB bridge. **PCLK** For peripheral operation. **PCLKG** Gated **PCLK** for APB bus interface logic. It has the same frequency and same phase as **PCLK**. Tie LOW, when there are no APB activities. The **APBACTIVE** output signal controls the gating.

The example APB subsystem is designed primarily for little-endian configuration. The peripherals are designed with the little-endian programmers model. The big-endian parameter is introduced to permit ARM to perform system-level tests to verify the bus components behavior in the big-endian configuration, and to assist the system designers to evaluate the processor in the big-endian configuration. Use of the big-endian parameter is not recommended for actual product development, because this adds extra hardware. Ideally, you must modify the peripherals for the big-endian systems to use the big-endian programmers model.

4.7.1 Programmers model

Table 4-25 shows the subsystem memory map.

Table 4-25 APB subsystem memory map

Offset value	Device
`0x0000`	Timer 0
`0x1000`	Timer 1
`0x2000`	Dual Timer
`0x3000`	Not used[a]
`0x4000`	UART 0
`0x5000`	UART 1
`0x6000`	UART 2
`0x7000`	Not used[a]
`0x8000`	Watchdog
`0x9000` `0xA000`	Not used[a]
`0xB000`	APB test slave for validation purpose
`0xC000`	APB expansion port 12
`0xD000`	APB expansion port 13
`0xE000`	APB expansion port 14
`0xF000`	APB expansion port 15

a. The corresponding port of the APB slave multiplexer is disabled by a Verilog parameter.

Table 4-26 shows the APB subsystem IRQ assignments.

Table 4-26 APB subsystem IRQ assignments

IRQ	Device
0	UART 0 receive interrupt
1	UART 0 transmit interrupt
2	UART 1 receive interrupt
3	UART 1 transmit interrupt

Table 4-26 APB subsystem IRQ assignments (continued)

IRQ	Device
4	UART 2 receive interrupt
5	UART 2 transmit interrupt
6, 7	Not used in the APB subsystem[a]
8	Timer 0
9	Timer 1
10	Dual-input timer
11	Not used
12	UART 0 overflow interrupt
13	UART 1 overflow interrupt
14	UART 2 overflow interrupt
15	Not used in APB subsystem[b]
16-31	Not used in APB subsystem[a]

a. Reserved for GPIO in AHB.
b. Reserved for DMA.

4.7.2 Signal descriptions

The APB subsystem contains the following non-AMBA signals in its interface:

- *Clock and reset signals*
- *UART signals* on page 4-31
- *Timer signals* on page 4-31
- *Watchdog signals* on page 4-31
- *Interrupt signals* on page 4-31
- *APB expansion port signals* on page 4-32.

Clock and reset signals

Table 4-27 shows the APB subsystem clock and reset signals.

Table 4-27 APB subsystem clock and reset signals

Signal	Description
PCLKEN	Clock enable for the APB interface. The AHB to APB bridge uses this signal so that you can run the APB operation at a lower speed than the AHB. The APB peripherals in the example system use the divided clock, **PCLK** and **PCLKG**, and therefore these peripherals ignore this signal.
APBACTIVE	The AHB to APB bridge generates this signal. It enables you to handle clock gating for gated APB bus clock, **PCLKG** in the example system. When there is no APB transfer, you can stop the gated APB bus clock to reduce power.

UART signals

The subsystem includes UART 0, UART 1, and UART 2. These signals are connected to a pin multiplexer of the example system to interface with external I/O. Table 4-28 shows the APB subsystem UART signals.

Table 4-28 APB subsystem UART signals

Signal	Description
uart*n*_rxd	Receive data
uart*n*_txd	Transmit data
uart*n*_txen	Transmit enable

Timer signals

The timer signals are connected to a multiplexer pin of the example system to interface with external I/O. Table 4-29 shows the APB subsystem timer signals.

Table 4-29 APB subsystem timer signals

Signal	Description
timer0_extin	Timer 0 external input
timer1_extin	Timer 1 external input

Watchdog signals

In the example system, the watchdog interrupt is connected to the *Non-Maskable Interrupt* (NMI) signal of the processor, and the watchdog reset signal is connected to the reset generator of the microcontroller system. Table 4-30 shows the APB subsystem watchdog signals.

Table 4-30 APB subsystem watchdog signals

Signal	Description
watchdog_interrupt	Watchdog interrupt
watchdog_reset	Watchdog reset

Interrupt signals

In the example microcontroller system design, this signal is merged with the other interrupt signals, and connected to the *Nested Vectored Interrupt Controller* (NVIC) of the Cortex-M processor. Table 4-31 shows the APB subsystem interrupt signal

Table 4-31 APB subsystem interrupt signal

Signal	Description
apbsubsys_interrupt	APB subsystem interrupt

APB expansion port signals

These are:

- APB expansion port 13
- APB expansion port 12
- APB expansion port 14
- APB expansion port 15.

If required, these ports permit the connection of additional APB slaves. If you do not use these ports, you can disable them using a Verilog parameter to avoid unused logic. Table 4-32 shows the APB expansion port signals.

Table 4-32 APB subsystem APB expansion port signals

Signal	Description
ext*n*_psel	APB expansion port *n*, select
ext*n*_pready	APB expansion port *n*, ready
ext*n*_prdata[31:0]	APB expansion port *n*, read data
ext*n*_pslverr	APB expansion port *n*, slave error

4.7.3 APB test slave

A simple APB test slave is included for verification purposes. ARM uses the test slave to verify the handling of wait states and error responses in the AHB to APB bridge. The APB test slave contains a software-programmable register that supports word, half word and byte size accesses.

Programmers model

Table 4-33 shows the APB test slave memory map.

Table 4-33 APB test slave memory map

Base offset	Type	Reset value	Description
`0x000`	R/W	`0x00000000`	Data Register, 32 bits. Zero wait state, two **PCLK** cycles per access.
`0x004`	R/W	`0x00000000`	Alias of Data Register, with one wait state.
`0x008`	R/W	`0x00000000`	Alias of Data Register, with two wait states.
`0x00C`	R/W	`0x00000000`	Alias of Data Register, with three wait states.
`0x010 - 0x0EF`	R/W	-	Reserved. Write is ignored and read 0.
`0xF0`	R/W	`0x00000000`	Alias of Data Register, with zero wait states and error responses.
`0xF4`	R/W	`0x00000000`	Alias of Data Register, with one wait state and error response.
`0xF8`	R/W	`0x00000000`	Alias of Data Register, with two wait states and error responses.
`0xFC`	R/W	`0x00000000`	Alias of Data Register, with three wait states and error responses.
`0x100 - 0xFFF`	R/W	-	Reserved. Write is ignored and read 0.

4.8 Timeout monitor

The APB timeout monitor, `apb_timeout_mon.v`, prevents an APB slave from locking up a system. It is placed between an APB master and an APB slave, and connected directly to the APB slave. If there is an active transfer to the slave, and the slave holds the **PREADY** signal LOW for more than a certain number of clock cycles, the monitor generates an error response to the bus master.

If the bus master generated any subsequent access to this slave, the monitor returns an error response and blocks the access to the slave until the slave has asserted its **PREADY** HIGH.

Figure 4-24 shows the APB timeout monitor module.

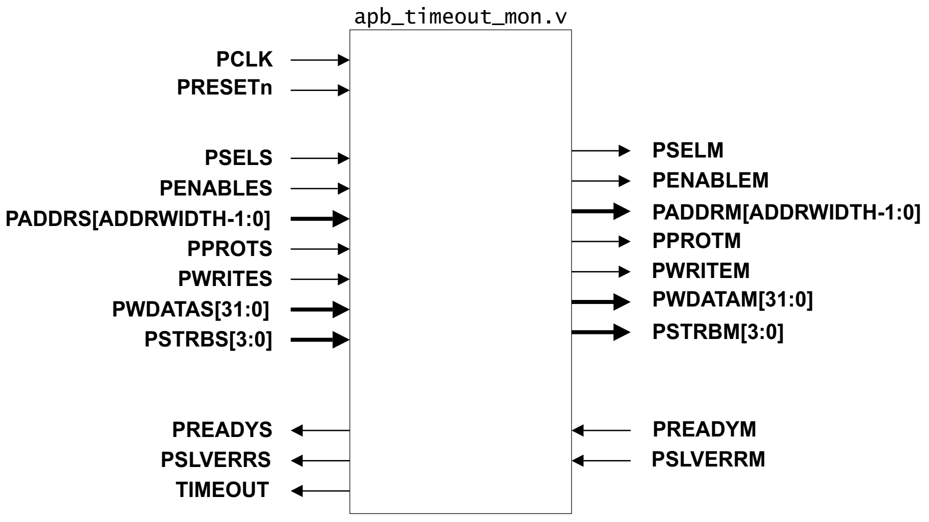


Figure 4-24 APB timeout monitor

If multiple APB slaves require monitoring, each of them might require its own APB timeout monitor, unless the bus fault handler does not require access to the blocked APB bus segment and therefore can work during a blocking state. See Figure 4-25.

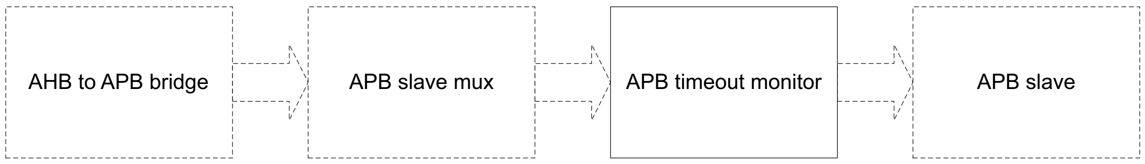


Figure 4-25 Use of APB timeout monitor

Table 4-34 shows the characteristic of the APB timeout monitor.

Table 4-34 APB timeout monitor characteristics

Element name	Description
Filename	`apb_timeout_mon.v`

Parameter	The parameters are as follows:
	`ADDRWIDTH`
	Width of APB address bus. The default value is 12.
	`TIME_OUT_VALUE`
	Number of wait state cycles that trigger timeout. The value can vary from 3-1024, and the default value is 16.

Clock domain	**PCLK** for APB operation.

Chapter 5
Advanced AHB Components

This chapter describes the advanced AHB components that the Cortex-M System Design Kit uses. It contains the following sections:

——— **Note** ———

The advanced AHB components are available only with the Cortex-M System Design Kit, full version. They are not included in the Cortex-M0 System Design Kit.

———————————

5.1 Bus matrix

In the Cortex-M System Design Kit, the bus matrix component provides lower latency solution. The following subsections describe the bus matrix configurable features and operation:

5.1.1 Key features

The bus matrix has the following key features:

- number of slave ports can be 1-16
- number of master ports can be 1-16
- routing data width can be 32 bits or 64 bits
- routing address width can be 32-64 bits
- architecture type, AHB and ARM11 extensions:
  - AHB2, supports an AHB 2.0 interface, this is the default
  - V6, supports all ARM11 AHB extensions
  - exclusive, excl supports the ARM11 exclusive access extensions only
  - unalign, supports the ARM11 unaligned access extensions only.
- arbiter type that can be round-robin, fixed, or burst
- default slave included with each slave port
- optional **xUSER** signals, that can be 0-32 bits, with zero meaning excluded
- sparse connectivity:
  - The sparse connectivity feature removes any unnecessary connections, and this reduces area and multiplexer delays.
  - Separate instances of the output stage and output arbiter are generated for each master port.
  - For input-output stages with only one sparse connection, the choice of arbiter is overridden with single arbiter and output stage modules. These single modules also permit 1x*n* interconnects.
- design entry by command line where the address map is calculated, but this excludes REMAP support
- design entry by XML configuration file that enables you to specify an address map, and includes REMAP support
- user-specified module names or automatically derived top-level name
- user-specified source and target directories

- optional `` `timescale `` Verilog directives.

5.1.2 Bus matrix configurability

The bus matrix is a configurable component that enables you to connect multiple AHB masters to multiple AHB slaves.

The bus matrix RTL is generated automatically using the `BuildBusMatrix.pl` script. The script takes different configuration parameters, for example, the number of masters, number of slaves, and data-width, and then generates the corresponding Verilog RTL.

Alternatively, you can also create an XML file to explain the bus matrix design, and pass it on to the `BuildBusMatrix.pl` script to create the bus matrix.

Note

You must execute the `BuildBusMatrix.pl` script from the `logical/ahb_bus_matrix` directory. To get the help, enter:

```
bin/BuildBusMatrix.pl -help
```

5.1.3 Bus matrix module

The bus matrix module, `BusMatrix`, enables multiple AHB masters from different AHB buses to be connected to multiple AHB slaves on multiple AHB slave buses. It enables parallel access to a number of shared AHB slaves from a number of different AHB masters. The bus matrix determines the master that gains access to each slave, and routes the control signals and data signals between them. This block is required in multi-layer AHB systems.

Figure 5-1 on page 5-4 shows a block diagram of the bus matrix module.

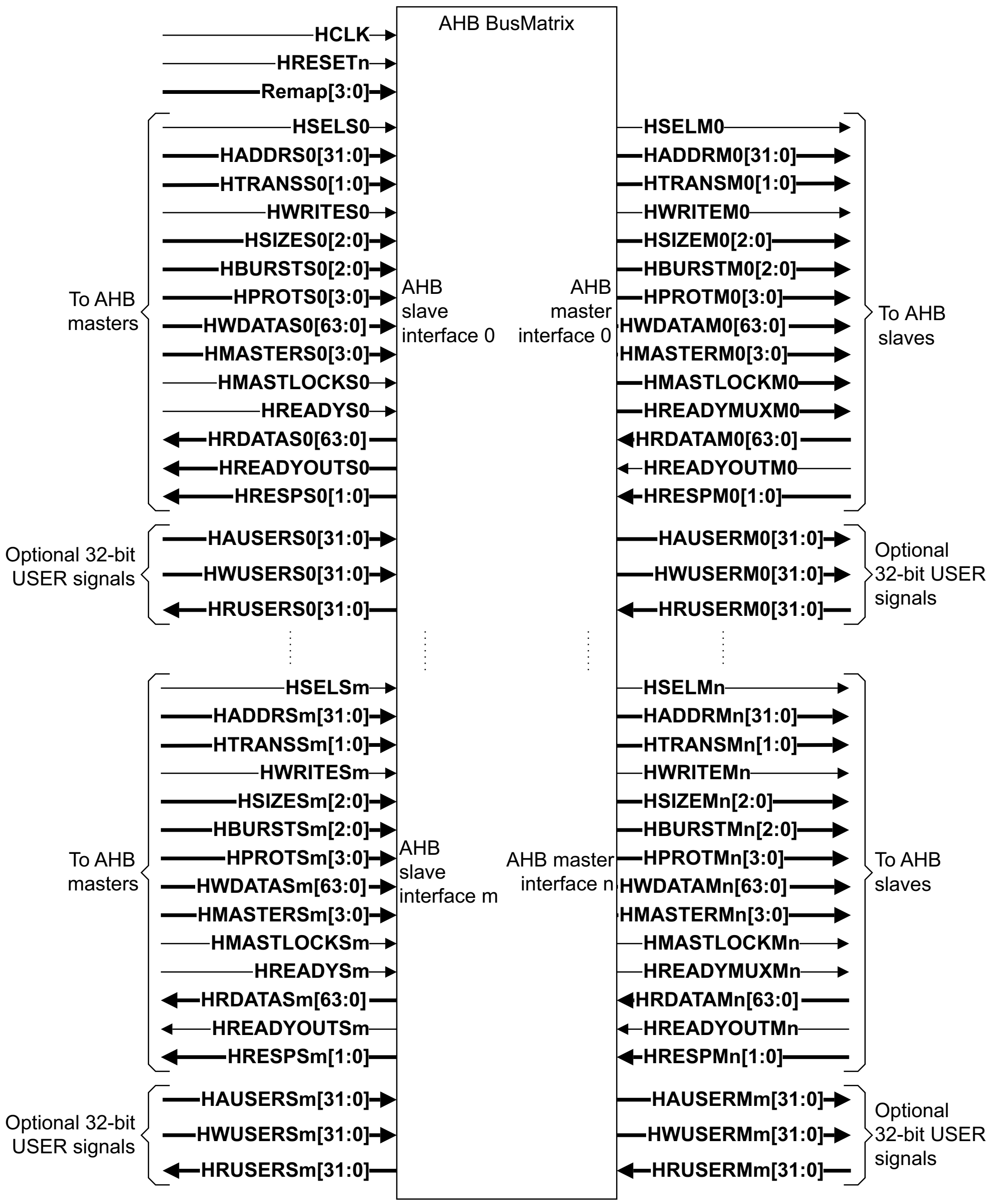


Figure 5-1 Bus matrix module components

Figure 5-1 shows a bus matrix module components block diagram for (*m*+1) input ports, (*n*+1) output ports, 64 bits routing data width, 32 bits routing address width, and 32 bits **USER** signal widths.

The bus matrix signal names have the following suffixes for port and pin naming:

- signals on the AHB slave interface from AHB masters have the suffix **S**
- signals on the AHB master interface to AHB slaves have the suffix **M**.

The bus matrix connects to the masters and slaves using this naming scheme, with an additional integer to identify the correct master and slave. For example, connect **HWDATAS0[63:0]** to the 64 bits AHB Master 0 write data port, and **HWDATAM0[63:0]** to the AHB Slave 0 write data port.

To maintain compatibility between the bus matrix and existing AHB components developed for AMBA 2.0, the **HRESP** signals are two bits. When you connect the AHB bus matrix to the other components in the Cortex-M System Design Kit, tie the extra **HRESP[1]** bit LOW for input, or leave it unconnected for output.

5.1.4 Operation

The following sections describe the operation of the bus matrix:

- *Integrating the bus matrix*
- *Locked sequences*
- *Full AHB and AHB-Lite*.

Integrating the bus matrix

When integrating the bus matrix component:

- The input ports, with signal suffix **S**, are AHB slave ports, and you must connect them accordingly.
- The output ports, with signal suffix **M**, are AHB slave gasket ports. That is, they attach directly to an AHB slave port, that they mirror. The AHB slave gasket port is not treated in the same way as a full AHB master port.
- If you want to use the output from a bus matrix as a bus master on an additional AHB layer, and if you require a high operational frequency, ARM recommends that you use a component such as an AHB bridge, for example, an AHB to AHB synchronous bridge or the `Ahb2AhbPass` component in the ARM *AMBA Design Kit* (ADK).

Note

When connecting to an output port on the bus matrix, you must connect the **HSEL** pin to the attached slave even if there is only one slave present. If you do not do this, the slave might see spurious transfers under certain circumstances.

Locked sequences

The bus matrix is only designed to support locked sequences that target a single output port. Because of this, you do not require a snooping bus across all input ports. This provides arbitration for locked transfers on all layers simultaneously. In addition, the bus matrix is not designed to cope with a SPLIT response to a locked transfer. If this occurs, the bus matrix correctly passes the SPLIT response back to the initiating master, but it might then enable another master, connected to a different input port, to access the output port that the first master targeted.

Full AHB and AHB-Lite

The bus matrix inherently supports both full AHB and AHB-Lite systems. However, you must take care with SPLIT responses. The bus matrix correctly passes back a SPLIT response, but then relies on an arbiter on the AHB layer connected to the relevant input port to ensure that the initiating master is degranted until the slave un-splits it.

5.1.5 Programmers model

The design of the bus matrix consists of an input stage, a decode stage, and an output stage that *Block functionality* describes. Figure 5-2 shows a bus matrix design with:

- four slave ports, for connection to bus masters

- three master ports, for connection to slaves.

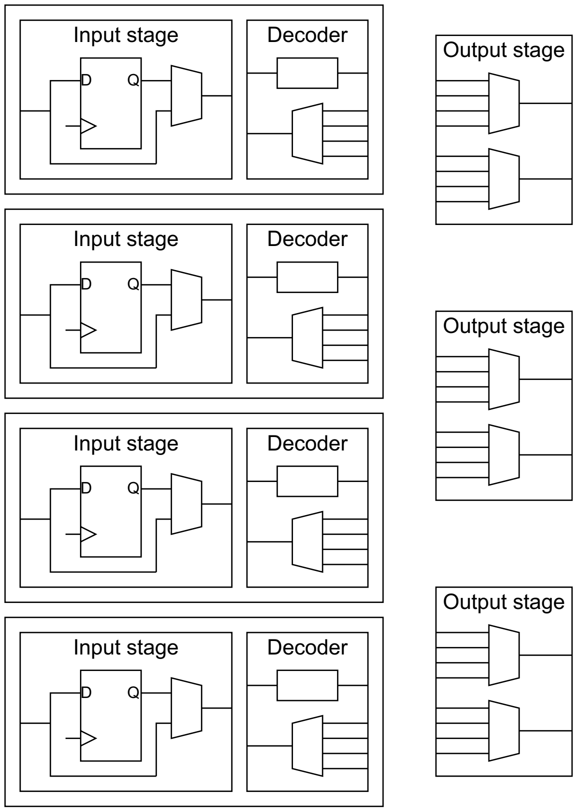


Figure 5-2 Example bus matrix design configuration

5.1.6 Block functionality

The following sections describe the functionality of the bus matrix module:

- *Input stage*
- *Decode stage* on page 5-6
- *Output stage* on page 5-7.

Input stage

The input stage provides the following functions:

- It registers and holds an incoming transfer if the receiving slave is not able to accept the transfer immediately.
- If the bus matrix switches between input ports while in the middle of an undefined length burst, the input stage modifies the **HTRANS** and **HBURST** signals for the interrupted input port, so that when it is reinstated, the remaining transfers in the burst meet the AHB specification.

Decode stage

The decode-stage generates the select signal for individual slaves. It also handles the multiplexing of response signals and read data. During the address phase of a transfer, the decoder asserts the slave-select signal for the appropriate output stage corresponding to the address of the transfer. In addition, the decoder routes an active signal from the output stage back to the input stage. This signal indicates to the input that its address is currently being driven onto the chosen slave. During the data phase of a transfer, the decoder routes the response signals and read data back to the input port.

Each slave port, connected to an AHB master, is associated with a separate decoder. This enables the AHB masters to have independent address maps, that is, a shared slave is not required to appear in the same address location for all masters. This is typically useful for multi-processor systems.

Any gaps in the memory map are redirected to a default slave, that returns an OKAY or ERROR response depending on the type of access. An instance of a default slave is associated with each decoder.

The decoder stage also supports the system address Remap function. A 4 bits Remap control signal connects to the decoder. You can use remapping to change the address of physical memory or a device after the application has started executing. This is typically done to permit RAM to replace ROM when the initialization has been completed.

In multi-layer AHB systems that have local slaves on some of the AHB layers, the address decoding is performed in two stages. The first address decoder selects between local slaves and the shared slaves available through the AHB bus matrix module. To support this, the decode-stage within the bus matrix includes an **HSEL** input that indicates whether the address from an input port is destined for a shared slave.

Output stage

The output stage has the following functions:

- selects the address and control signals from the input stages
- selects the corresponding write data from the input stage
- determines when to switch between input ports in the input stage.

The output stage only selects an input source when that input has a transfer in the holding register.

The output stage generates an active signal for each input port when the address from that input port is being driven onto the slave. This signal enables the input stage to determine when to hold up transfers from other masters because the slave is not currently available.

When a sequence of transfers to a shared slave has finished, and there are no more transfers to the slave required by any of the input ports, the output stage switches the address and control signals to an idle state.

5.1.7 Arbitration and locked transfers

This section describes:

- *Arbitration* on page 5-7
- *Locked transfers* on page 5-8.

Arbitration

The arbitration within the bus matrix module determines the input port that has access to the shared slave, and each shared slave has its own arbitration. Different arbitration schemes provide different system characteristics in terms of access latency and overall system performance.

The slave switch supports the following arbitration schemes:

Fixed arbitration

One port always has the highest priority and the order of priority for all other ports is fixed.

You can break-up burst transfers, if a higher-priority master requests the same slave, except where the burst transfer is a locked transfer.

Fixed (burst) arbitration

This is similar to fixed arbitration but it does not break defined length burst transfers and it is the default arbitration for the bus matrix.

Round-robin arbitration

Arbitration is performed during every active clock cycle, indicated by **HREADYM**. Priority initially goes to the lowest-numbered requestor, that is input port 0. When multiple requests are active, priority goes to the next lowest-numbered requestor compared to the currently active one. Fixed-length bursts are not broken. The arbitration waits for the end of the burst before passing control to the next requestor, if one exists. INCR bursts are treated as four-beat bursts, to optimize memory accesses, with guard logic to ensure that a sequence of short INCR bursts does not freeze the arbitration scheme.

Locked transfers

Using a multi-layer AHB system requires certain restrictions to be placed on the use of locked transfers to prevent a system deadlock. It is required that a sequence of locked transfers is performed to the same slave within the system. Because the minimum address space that you can allocate to a single slave is 1KB, a bus master can ensure that this restriction is met by ensuring that it does not perform a locked sequence of transfers over a 1KB boundary, ensuring that it never crosses an address decode boundary.

Therefore, if a bus master is to perform two locked transfer sequences to different address regions, the bus master must not start the second locked transfer sequence until the final data phase of the first locked transfer sequence has completed.

5.1.8 Address map

If you do not use the XML configuration method, you can use command line parameters instead. In that case, the address map is calculated automatically as follows:

- Figure 5-3 on page 5-8 shows the equations that enable the address map to be divided into a number of regions depending on the number of master ports:

$$\text{regions} = \text{round\_to\_highest\_2toN(total\_master\_ports)}$$

$$\text{region\_size} = \frac{2^{\text{routing\_address\_width}}}{\text{regions}}$$

$$\text{region\_base} = \text{region\_size} \times \text{master\_port\_instance}$$

$$\text{region\_top} = \text{region\_base} + \text{region\_size} - 1$$

Figure 5-3 Region equations

- Each slave port has the same decoder instance.

- No Remap support.

If you are using XML configuration method, then the decode-stage can have a fully-customized address map, and each slave port can have an independent view of the address space. Example 5-1 shows a slave port address map description.

Example 5-1 Slave port address map description

```
<slave_interface name="SI1">
    <address_region interface="MI0" mem_lo="40000000" mem_hi="4fffffff" remapping="move"/>
    <address_region interface="MI0" mem_lo="70000000" mem_hi="7fffffff" remapping="alias"/>
    <address_region interface="MI1" mem_lo="80000000" mem_hi="9fffffff" remapping="none"/>
    <address_region interface="MI2" mem_lo="a0000000" mem_hi="bfffffff" remapping="move"/>
    <address_region interface="MI3" mem_lo="00000000" mem_hi="1fffffff" remapping="move"/>

    <remap_region   interface="MI0" mem_lo="00000000" mem_hi="1fffffff" bit="0"/>
    <remap_region   interface="MI1" mem_lo="50000000" mem_hi="5fffffff" bit="0"/>
    <remap_region   interface="MI2" mem_lo="60000000" mem_hi="6fffffff" bit="1"/>
    <remap_region   interface="MI3" mem_lo="c0000000" mem_hi="dfffffff" bit="0"/>
</slave_interface>
```

Address region

The address region parameters determine the routing of transactions to the master interfaces. Each master interface can have multiple non-contiguous address regions, when multiple sets of address region parameters are defined. However, the address regions of different master interfaces must not overlap. The `mem_lo` parameter defines the lower bound address and the `mem_hi` parameter defines the upper bound address for the master interface.

The `remapping` configuration parameter defines the behavior of master interfaces that support address remapping. It becomes active when the relevant REMAP bit is set. The following types of address remapping behavior exist:

- if you set the `remapping` parameter to `alias` or `none`, the remapping creates an alias of the defined region in the new address space
- if you set the `remapping` parameter to `move`, the address region is removed from the original address space and the master interface appears at the location defined by the remap region in the new address space.

Remap region

These regions are activated when using the remap facility, and each remap region is associated with a bit of the **REMAP** signal.

When the relevant remap bit is set, the remap regions take higher priority than normal address regions for the same master interface. Furthermore, any normal regions that have the remapping parameter set to `move`, are removed from the address space. If more than one bit is asserted for the same master interface, the least significant bit takes priority.

Figure 5-4 on page 5-10 shows the address map of the slave interface, defined in Example 5-1 on page 5-9, at different remap states.

The address map is explained at the remap state `REMAP = 0001` as follows:

- Normally, the address map, MI0, appears at two non-contiguous regions, `0x40000000` and `0x70000000`. When you set remap bit to 0, `0x40000000` region is removed because the remapping parameter is set to `move` and MI0 appears at the new remap region `0x00000000` to `0x1FFFFFFF`. The MI0 region at `0x70000000` is not removed because its remapping parameter is declared as `alias`.
- When you set remap bit to 0, MI1 appears at the new remap region, `0x50000000` to `0x5FFFFFFF`. The `0x80000000` region did not change because its remapping is set to `none`.
- MI2 did not change even though its remapping is declared as `move`, because it is associated with remap bit one. Remap bit one is not set at the current remap state.
- MI3 is moved to a new base address `0xC0000000`.

Note

You can consider MI0 as ROM and MI3 as RAM. At boot time, the **REMAP** signal is set to `0001` and you can observe ROM at base address `0x00000000`. After booting, the **REMAP** signal is set to `0000`, the RAM now appears at `0x00000000`, and the ROM is moved up in the address space to `0x40000000`.

Figure 5-4 on page 5-10 shows the address map at different remap states.

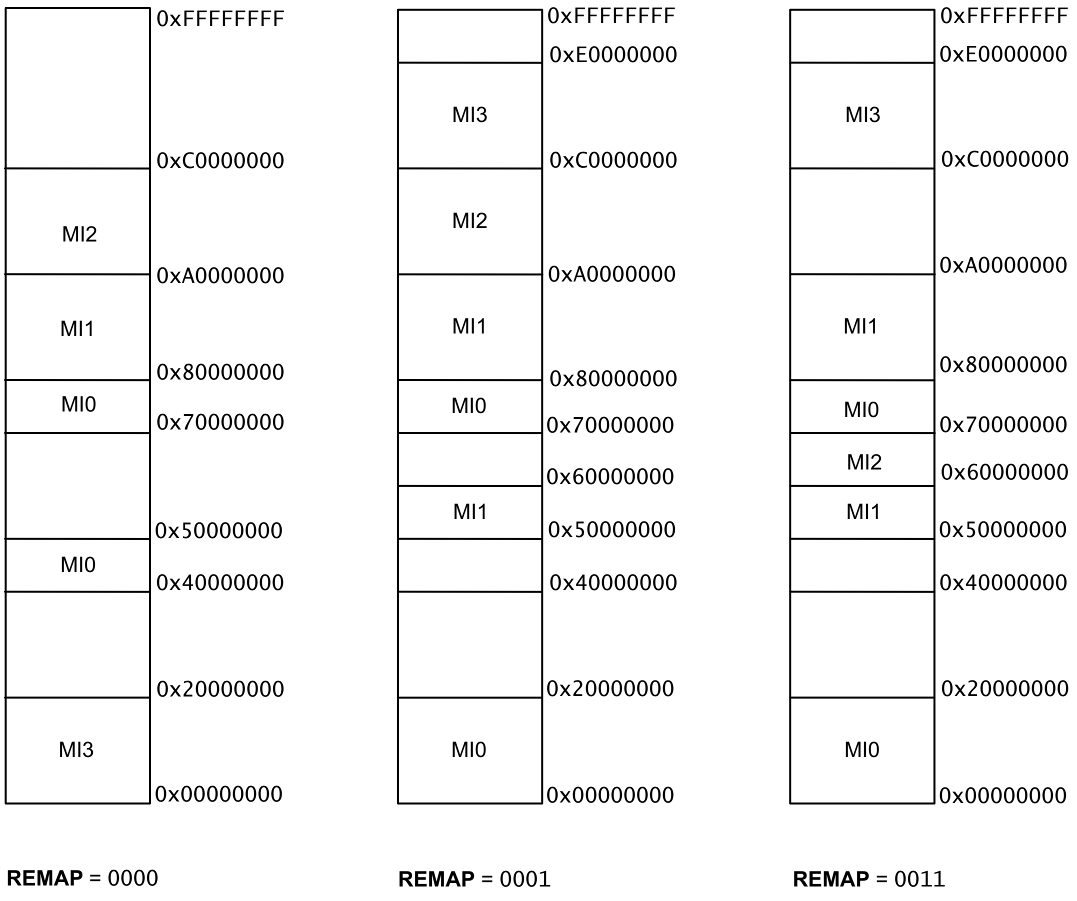


Figure 5-4 Address map at different remap states

5.1.9 Signal descriptions

Table 5-1 shows the signals for the bus matrix.

Table 5-1 Bus matrix signals

Signal	Direction	Description
HCLK	Input	System bus clock. Logic is triggered on the rising edge of the clock.
HRESETn	Input	Activate LOW asynchronous reset.
System address control		
REMAP[3:0]	Input	System address remap control.
Interface to masters, AHB slave		
HADDRSx[N]	Input	N-bit address bus from AHB master. The value of N can vary from 31-63.
HBURSTSx[2:0]	Input	Burst size information.
HMASTERSx[3:0]	Input	Current active master.
HMASTLOCKSx	Input	Indicates that the transfer on the master AHB is a locked transfer.
HPROTSx[3:0]	Input	Protection information.
HRDATASx[63:0 or **31:0]**	Output	Read data to bus master. You can configure the width to either 64 bits or 32 bits wide.
HREADYOUTSx	Output	**HREADY** signal feedback to the master bus, indicating whether the AHB bus matrix module is ready for the next operation.
HREADYSx	Input	**HREADY** signal on the master AHB bus, indicating the start or end of a transfer.
HRESPSx[1:0]	Output	Response from the AHB bus matrix module to the AHB master. The width depends on the architecture choice.
HSELSx	Input	Active HIGH select signal to indicate that a shared slave connected to the AHB bus matrix module is selected.
HSIZESx[2:0]	Input	Size of the data.
HWDATASx[63:0 or **31:0]**	Input	Write data from AHB masters. You can configure the width to be either 64 or 32 bits wide.
HWRITESx	Input	Indicates a read or write operation.
Interface to slaves (AHB master)		
HADDRMx[N]	Output	N-bit address bus for the AHB slave. The value of N can vary from 31-63.
HBURSTMx[2:0]	Output	Burst size information.
HMASTERMx[3:0]	Output	Currently active master.
HMASTLOCKMx	Output	Indicates that the transfer on the AHB slave is a locked transfer.
HPROTMx[3:0]	Output	Protection information.
HRDATAMx[63:0 or **31:0]**	Input	Data read back from AHB slaves. You can configure the width to be either 64 bits or 32 bits wide.
HREADYOUTMx	Input	**HREADY** from the AHB slave or slave multiplexer.

Table 5-1 Bus matrix signals (continued)

Signal	Direction	Description
HREADYMUXMx	Output	**HREADY** feedback to all slaves on the AHB slave.
HRESPMx[2:0]	Input	**HRESP** from the AHB slave or slave multiplexer. The width depends on the architecture choice.
HSELMx	Output	Active HIGH select signal to indicate that the slave bus is accessed. You can use this signal to drive a single AHB slave directly, or drive a secondary AHB decoder if you use multiple AHB slaves.
HSIZEMx[2:0]	Output	Size of the data.
HWDATAMx[63:0 or **31:0]**	Output	Write data to AHB slaves. You can configure the width to be either 64 bits or 32 bits wide.
HWRITEMx	Output	Indicates a read or write operation.
USER signals		
HAUSERSx	Input	Additional sideband bus that has the same timing as the slave interface address payload signals.
HWUSERSx	Input	Additional sideband bus that has the same timing as the slave interface write data payload signals.
HRUSERSx	Output	Additional sideband bus that has the same timing as the slave interface read data payload signals.
HAUSERMx	Output	Additional sideband bus that has the same timing as the master interface address payload signals.
HWUSERMx	Output	Additional sideband bus that has the same timing as the master interface write data payload signals.
HRUSERMx	Input	Additional sideband bus that has the same timing as the master interface read data payload signals.

USER signals

The bus matrix supports **USER** signals on master and slave interfaces. These signals are optional, and a value of 0 on the `user_signal_width` parameter removes them from the generated Verilog. If the `user_signal_width` parameter or the `--userwidth` command line switch is set to a non-zero value, that value defines the width of those **USER** signals. The **USER** signals have the same timing as the payload signals for that channel. For example, the **HAUSER** signals have the same timing as the address payload signals.

The **USER** signals are:

- **HAUSER**
- **HRUSER**
- **HWUSER**.

N-bit addressing

The bus matrix supports N-bit addressing, that is, you can configure the address bus to be 32-64 bits. By default, the address width is set to 32 bits, but you can change this by setting the `--addrwidth` command line switch or by changing the `routing_address_width` global parameter in the XML file. Setting the address width affects both the address buses for the slave ports and master ports.

——— **Note** ———

The presence of **USER** signals and the support of N-bit addressing enables the bus matrix to fully connect to a network interconnect product such as the PrimeCell High Performance Matrix PL301. The bus matrix **USER** signals are fully mapped to their AXI counterparts. This is typically useful in mixed protocol designs. See the *CoreLink Network Interconnect NIC-301 Technical Reference Manual* for more information.

5.2 AHB upsizer

The following subsections describe the AHB upsizer features and its operation:

- *Overview*
- *Method of using AHB upsizer*.

5.2.1 Overview

The AHB upsizer, `ahb_upsizer64.v`, permits a 32 bits AHB bus master to connect to a 64 bits AHB slave. Figure 5-5 shows the AHB upsizer module.

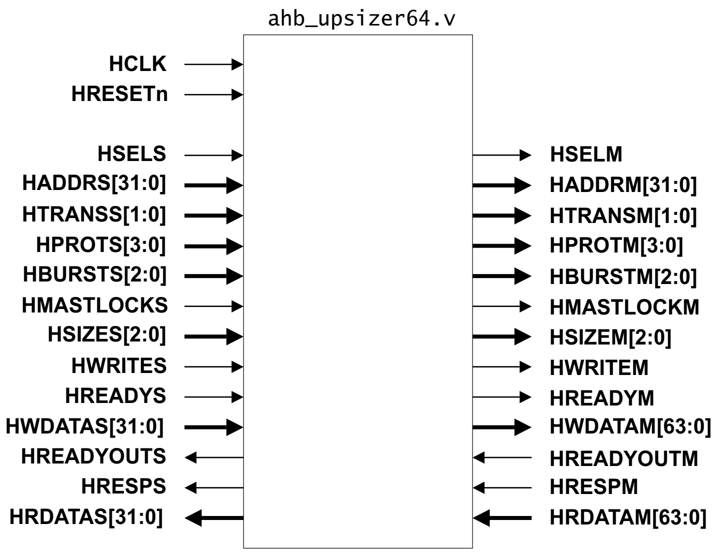


Figure 5-5 AHB upsizer

Table 5-2 shows the characteristics of the AHB upsizer.

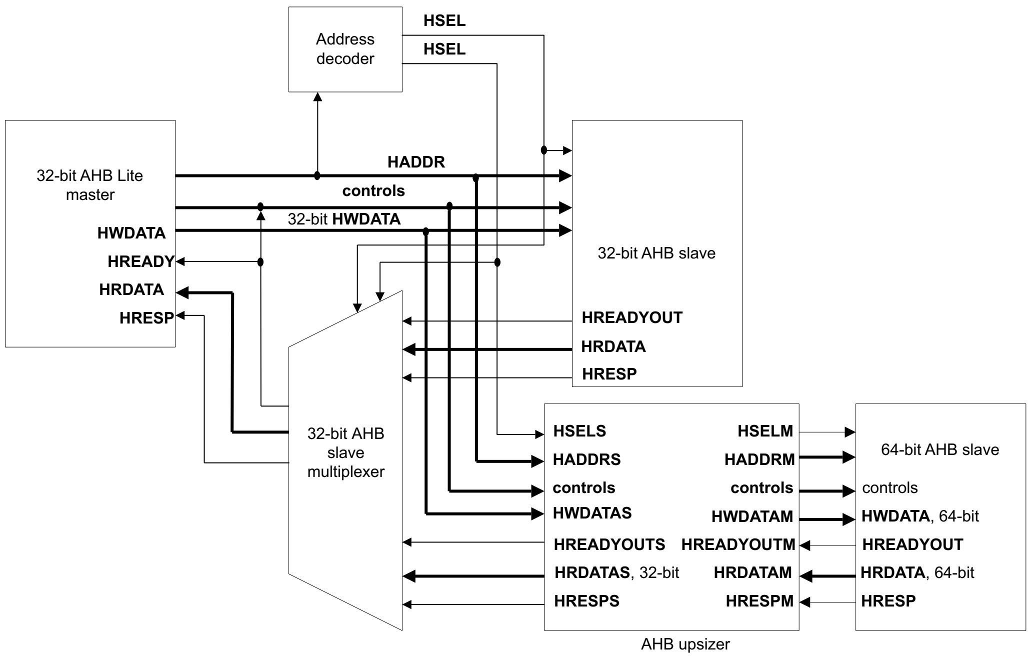
Table 5-2 AHB upsizer characteristics

Element name	Description
Filename	`ahb_upsizer64.v`
Parameters	None
Clock domain	**HCLK**

The AHB upsizer handles the routing of data only and does not modify the transfer type or response information.

5.2.2 Method of using AHB upsizer

You can connect the AHB upsizer in a number of ways with varied combinations of 32 bits or 64 bits AHB Lite systems. For example, you can couple the AHB upsizer directly with a 64 bits slave as Figure 5-6 on page 5-15 shows.



Note: The controls included are **HTRANS**, **HWRITE**, **HSIZE**, **HPROT**, and **HBURST**.

Figure 5-6 Using AHB upsizer, type one

If there is more than one 64 bits AHB slave in the AHB segment, it is possible to share an AHB upsizer as Figure 5-7 shows.

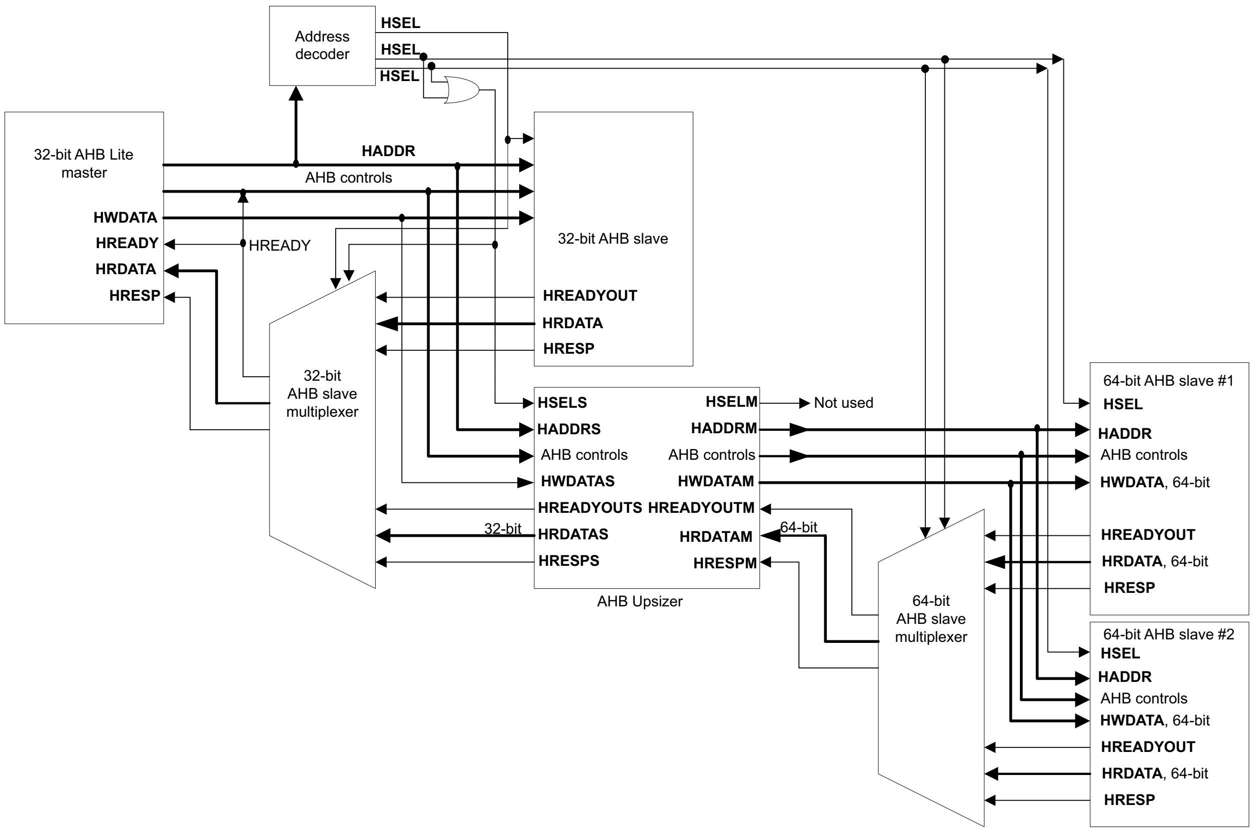


Figure 5-7 Using AHB upsizer, type two

You can use the **HSEL** signals generated from the 32 bits bus directly on the 64 bits AHB slaves because the AHB upsizer does not change the behavior of the **HSEL** signals. This arrangement avoids the requirement to have two AHB decoders in the system.

5.3 AHB downsizer

The following subsections describe the AHB downsizer features and its operation:

- *Overview*
- *Programmers model* on page 5-18
- *Signal descriptions* on page 5-22
- *Using AHB downsizer* on page 5-23.

5.3.1 Overview

The AHB downsizer module, `ahb_downsizer64.v`, permits a 64 bits AHB bus master to connect to a 32 bits AHB slave. The downsizer module reduces the width of the data bus by half from an AHB master to an AHB slave. You can use full-width master transfer, this process involves modification of the transfer type, burst, and size, and latching half of the master read data. In addition, you might require multiple slave writes or reads to transfer data to and from the narrow slave.

Figure 5-8 shows the signal interface of the downsizer module.

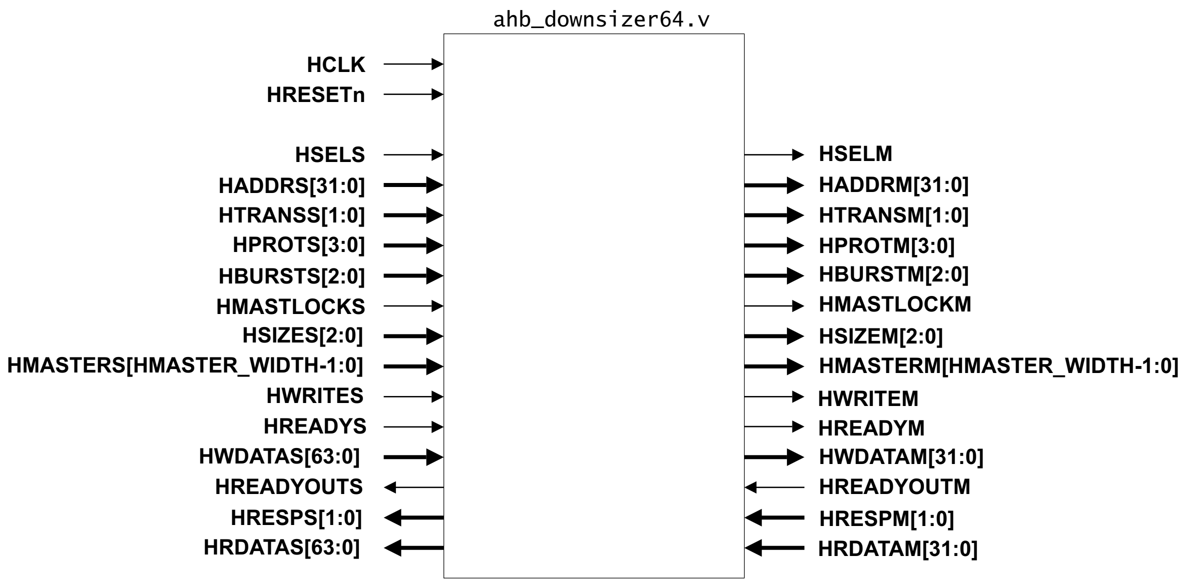


Figure 5-8 Downsizer module

Table 5-3 shows the characteristics of the AHB downsizer.

Table 5-3 AHB downsizer characteristics

Element name	Description	
Filename	`ahb_downsizer64.v`	
Parameter	`HMASTER_WIDTH`	Width of **HMASTER**. This is set to 1 by default.
	`ERR_BURST_BLOCK_ALL`	When this is set to 1, if an error response is received during a burst sequence, the remaining transfers in the burst sequence are blocked by the AHB Downsizer and do not reach the downstream 32 bits AHB. The AHB downsizer returns an error response to each of the remaining transfers remains in the burst sequence. This behavior applies to 64 bits, 32 bits, 16 bits, and 8 bits transfers. When this is set to 0, the same blocking behavior applies to 64 bits burst transfers only. Burst of other transfer sizes do not have this blocking behavior. See *Burst blocking after error* on page 5-20.
Clock domain	**HCLK**	

5.3.2 Programmers model

The following sections describe the programming details for the downsizer:

- *Downsizer transfers*
- *Unsupported transfers* on page 5-20
- *Burst blocking after error* on page 5-20
- *Slave responses* on page 5-21
- *Modification of control signals* on page 5-21.

Downsizer transfers

You can use the following options for downsizer transfers:

Downsizer not selected

When the **HSELS** signal of the downsizer module is LOW, the transfer size is passed to the 32 bits AHB, and **HSELM** is driven LOW. The 32 bits slaves must ignore the transfers by monitoring **HSELM** and **HADDRM**. **HREADYS** from the 64 bits bus is output to **HREADYM**. All 32 bits devices connected to the 32 bits AHB must monitor this **HREADYM** signal to determine the end of the current transfer, and the start of the next transfer.

Narrow transfers, downsizer selected

If the downsizer module is selected, and the transfer is 32 bits or less, the downsizer module passes the transfer through. All the control signals and responses from the slave are left unmodified. In this case, the only function of the downsizer is to route the appropriate half of the wide master write data bus to the narrow slave data bus for write transfers.

Read transfers require even less control, and the narrow slave read data is replicated across the wide master bus.

Table 5-4 shows the handling of narrow transfers.

Table 5-4 Narrow transfer handling

Transfer on 64 bits AHB	Transfer on 32 bits AHB	Address
32, 16, or 8 bits transfer	32, 16, or 8 bits transfer	**HADDR** passes through. If **HADDR[2]** = 0 then the **HWDATAS[31:0]** signals pass through. Otherwise, the **HWDATAS[63:32]** signals pass through. **HRDATAS** = **HRDATAM**, **HRDATAM**.

For 32, 16, and 8 bits transfers, **HWDATA** is selected by bit [2] of the transfer address. If this bit is set LOW, **HWDATA[31:0]** is routed to the 32 bits AHB. If this bit is set HIGH, bits [63:32] are routed.

If an ERROR, SPLIT, or RETRY response is received from the 32 bits slave, the downsizer module automatically terminates the current transfer by passing the response to the 64 bits bus. If the current transfer request on the 64 bits bus is a valid transfer, NON_SEQ or SEQ, it is captured by the registers in the downsizer module and is applied to the 32 bits AHB one cycle later. The downsizer module inserts a wait state on the 64 bits bus to ensure that the next transfer is not missed.

If the transfer is a burst, and an ERROR response is received from a 32 bits slave, the rest of the burst is blocked. You can disable the burst blocking behavior for 32, 16 and 8 bits burst transfers by setting the `ERR_BURST_BLOCK_ALL` verilog parameter to 0. See *Burst blocking after error* on page 5-20.

Wide transfers, downsizer selected

The role of the downsizer module is more complicated for 64 bits transfers. For both read and write transfers, the wide master transfers are broken down into two narrow slave cycles. The address to the slave is modified, to ensure that the two slave accesses go to different address locations. Table 5-5 shows the address line modification and data routing.

Table 5-5 Address line modification and data routing

Transfer on 64 bits AHB	Transfer on 32 bits AHB	Address
64 bits transfer	Cycle 1	**HADDR** passes through. **HWDATAS[31:0]** passes through. **HRDATAM** is stored in the downsizer module. **HADDRS[2:0]** must equal `000`.
	Cycle 2	**HADDRM[2]** is set to 1. **HWDATAS[63:32]** passes through. **HRDATAM** passes through to **HRDATAS[63:32]**. Previously stored data is output to **HRDATAS[31:0]**.

64 bits write transfers are split into two 32 bits transfers on two successive addresses. Table 5-5 on page 5-19 shows the generation of **HADDRM[2]** and the routing of write data. Because **HWDATAS** is stable during the two AHB transfers on the 32 bits AHB, no register is required to hold **HWDATA**.

During 64 bits read accesses, the construction of a full-width word for the master to read two slave accesses is required. The data from the first read is latched, and the data from the second read flows straight through the block. Bits [31:0] are always transferred in the first cycle, and bits [63:32] are transferred in the second cycle using the next word address. This transfer characteristic occurs independently of target system endianness.

If an ERROR, SPLIT, or RETRY response is received from the 32 bits slave, the response is passed to the 64 bits bus immediately. If this occurs on the first half of the 64 bits transfer, the second half of the transfer is not carried out.

If a two-cycle response is received, the downsizer module automatically aborts the current transfer by inserting an IDLE cycle on the 32 bits bus. If the current transfer request on the 64 bits bus is a valid transfer, NON_SEQ, the registers in the downsizer module capture it and apply it to the 32 bits AHB one cycle later. The downsizer module inserts a wait state on the 64 bits bus to ensure that the next transfer is not missed.

If the transfer is a burst, and an ERROR response is received from 32 bits slave, the rest of the burst is blocked.

Unsupported transfers

The downsizer module does not support the following transfer types:

Wide transfers

If the downsizer module receives a transfer request greater than 64 bits wide, with **HSELS** = 1, the response is undefined.

Unaligned transfers

Unaligned transfers are not supported.

Burst blocking after error

If an ERROR response is received from a 32 bits slave during a 64 bits burst, and if the 64 bits master continues the burst, the rest of the burst is blocked. During blocking, the ERROR response is fed back to the 64 bits AHB and an IDLE transfer is issued to the 32 bits AHB. The blocking ends when a nonsequential transfer request is detected, or if **HSELS** on the downsizer module is LOW. This feature ensures that there is no discontinuity in **HADDR** and **HTRANS**.

The blocking does not apply to 32, 16, or 8 bits transfers. In these cases, the rest of the transfer requests pass through as normal. If a busy cycle is detected during burst blocking, the downsizer module replies with an OKAY response. However, the subsequent SEQUENTIAL transfers are still blocked.

If the ERROR response occurs in the last cycle of the burst, no blocking is generated because the next transfer is an IDLE or NONSEQUENTIAL access. In this case, if the next access is nonsequential, the downsizer module issues an IDLE cycle on the 32 bits AHB in the second cycle of the ERROR response, stores the transfer control information, and applies it to the 32 bits AHB in the next cycle.

A wait state is inserted on the 64 bits bus to enable the 32 bits bus to catch up with the transfer.

Slave responses

To maintain compatibility with the bus matrix in the AMBA Design Kit, the **HRESP** signals are two bits. When you connect the AHB bus matrix to the other components in the Cortex-M System Design Kit, tie the extra **HRESP[1]** bit LOW for input, or leave it unconnected for output.

When a RETRY or SPLIT response is received, an IDLE cycle is issued to the 32 bits AHB in the second cycle of the RETRY or SPLIT response. If the response occurs during the first half of a 64 bits transfer, the second half is not completed. If the 64 bits master continues to output a valid transfer while the downsizer module is still selected, the transfer is stored and applied to the 32 bits AHB a cycle later. A wait state is output to the 64 bits bus to enable the 32 bits AHB to catch up.

In the case of SPLIT or RETRY responses during 64 bits transfers, the **HRDATA** value received is unpredictable and must be ignored.

Modification of control signals

Table 5-6 shows that, for both read and write transfers, the control signals are modified in the same way.

Table 5-6 Signal mapping when downsizer module is activated

Control signals	Master cycle type		Replaced by slave cycles	Comments
HTRANS	IDLE	to	IDLE	-
	BUSY	to	BUSY	-
	NONSEQ	to	NONSEQ, followed by a SEQ	No change if transfer is 8, 16, or 32 bits.
	SEQ	to	SEQ, followed by a SEQ	No change if transfer is 8, 16, or 32 bits. Exception for WRAP16 boundary, WRAP16 is mapped to INCR and NONSEQ is issued at 32-word boundary.
HADDR[2]	= 0	to	0 then 1	No change if transfer is 8, 16, or 32 bits.
	= 1	-	-	Not permitted for 64 bits transfer.
HSIZE	8, 16, or 32 bits	to	8, 16, or 32 bits	No conversion required.
	64 bits	to	32 bits	Conversion process activated.
	128 or 256 bits	to	32 bits	Not supported.

Table 5-6 Signal mapping when downsizer module is activated (continued)

Control signals	Master cycle type		Replaced by slave cycles	Comments
HBURST	SINGLE	to	INCR	No change if transfer is 8, 16, or 32 bits.
	INCR	to	INCR	No change if transfer is 8, 16, or 32 bits.
	INCR4	to	INCR8	No change if transfer is 8, 16, or 32 bits.
	WRAP4	to	WRAP8	No change if transfer is 8, 16, or 32 bits.
	INCR8	to	INCR16	No change if transfer is 8, 16, or 32 bits.
	WRAP8	to	WRAP16	No change if transfer is 8, 16, or 32 bits.
	INCR16	to	INCR	No change if transfer is 8, 16, or 32 bits.
	WRAP16	to	INCR	No change if transfer is 8, 16, or 32 bits. NONSEQ broadcast if WRAP boundary is reached.

5.3.3 Signal descriptions

Table 5-7 shows the signal connections for the downsizer module.

Table 5-7 Downsizer interface signals

Signal	Direction	Description
HCLK	Input	System bus clock. Logic is triggered on the rising edge of the clock.
HRESETn	Input	Activate LOW asynchronous reset.
64 bits AHB interface signals, AHB slave		
HADDRS[31:0]	Input	Address from the 64 bits AHB.
HBURSTS[2:0]	Input	Burst size information on the 64 bits AHB.
HMASTLOCKS	Input	Indicates that the transfer on the 64 bits AHB is locked.
HPROTS[3:0]	Input	Protection information on the 64 bits AHB.
HRDATAS[63:0]	Output	Read data to the 64 bits bus.
HREADYOUTS	Output	**HREADY** signal feedback to the 64 bits bus, indicating that the downsizer is ready for the next operation.
HREADYS	Input	**HREADY** signal on the 64 bits AHB bus, indicating the start and end of a transfer on the 64 bits bus.
HRESPS[1:0]	Output	Response from the downsizer module to the 64 bits bus.
HSELS	Input	Active HIGH select signal to indicate 32 bits memory range is accessed on the 64 bits AHB.
HSIZES[2:0]	Input	Size of the data on the 64 bits AHB.
HWDATAS[63:0]	Input	Write data from the 64 bits bus.
HWRITES	Input	Indication of a read or write operation on the 64 bits AHB.
32 bits AHB interface signals, AHB master		
HADDRM[31:0]	Output	Address for the 32 bits AHB.

Table 5-7 Downsizer interface signals (continued)

Signal	Direction	Description
HBURSTM[2:0]	Output	Burst size information on the 32 bits AHB.
HMASTLOCKM	Output	Indicates that the transfer on the 32 bits AHB is locked.
HPROTM[3:0]	Output	Protection information on the 32 bits AHB.
HRDATAM[31:0]	Input	Data read back from AHB slaves.
HREADYM	Output	**HREADY** feedback to all slaves on the 32 bits AHB.
HREADYOUTM	Input	**HREADY** from the 32 bits AHB slaves or slave multiplexer.
HRESPM[1:0]	Input	**HRESP** from the 32 bits AHB slaves or slave multiplexer.
HSELM	Output	Active HIGH select signal to indicate that a 32 bits bus is accessed. You can use this signal to drive a single AHB slave directly, or drive a secondary AHB decoder if you use a multiple 32 bits AHB slaves.
HSIZEM[2:0]	Output	Size of the data on the 32 bits AHB.
HWDATAM[31:0]	Output	Write data to the 32 bits AHB slaves.
HWRITEM	Output	Indication of a read or write operation on the 32 bits AHB.

Instead of reading **HREADY** from the 64 bits bus, or **HREADYOUT** from the 32 bits slave multiplexer, the AHB slaves on the 32 bits bus must read the **HREADYM** generated from the downsizer module. This signal is multiplexed between **HREADYOUTM**, when a slave attached to the M port of the downsizer is selected, including during 64 bits to 32 bits conversion, and **HREADYS**, when the downsizer is not selected.

During a conversion, the 64 bits transfer is split into two 32 bits transfers, and all the AHB slaves on the 32 bits AHB bus are able to read the **HREADY** signal that the activated 32 bits slave generates. However, this **HREADY** signal must not be passed onto **HREADY** in the 64 bits bus system because this requires the insertion of wait states for the second 32 bits AHB transfer. Because of this, an additional **HREADYM** signal enables the AHB slave to determine when the end of an AHB transfer has occurred.

5.3.4 Using AHB downsizer

You can place the AHB downsizer in a number of ways with varied combination of 32 bits or 64 bits AHB system. For example, you can couple the AHB downsizer directly with 32 bits slave in a 64 bits AHB system as Figure 5-6 on page 5-15 shows.

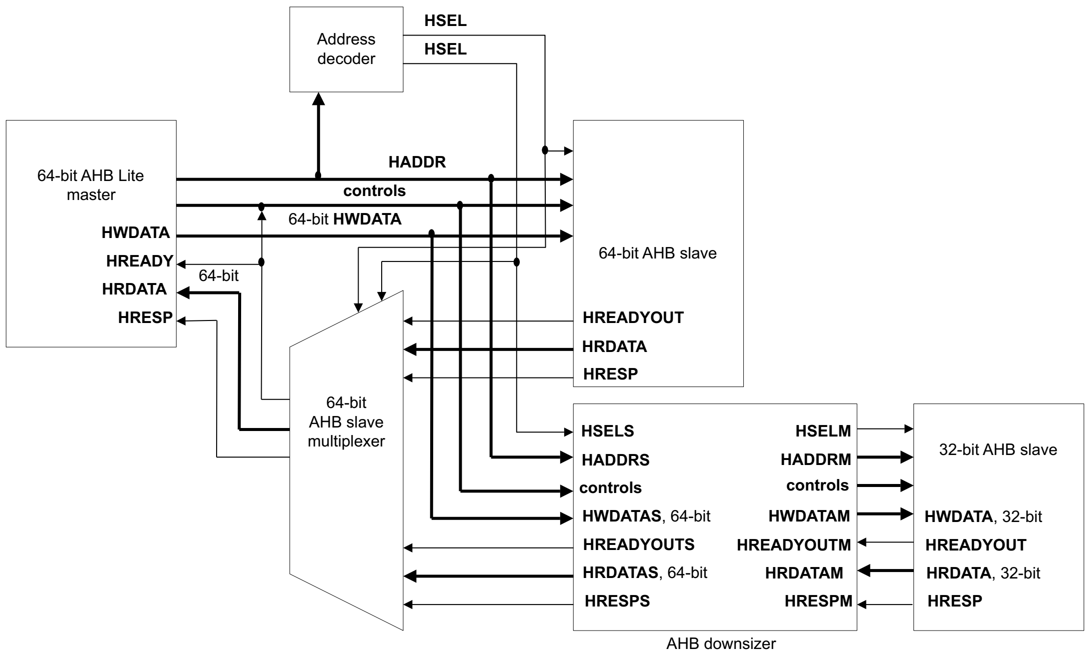


Figure 5-9 Using AHB downsizer, direct connection

You can also have one AHB downsizer to be shared between multiple 32 bits AHB slaves. The **HSEL** for the 32 bits AHB slaves must be derived from the **HSEL** output from the downsizer as Figure 5-10 shows.

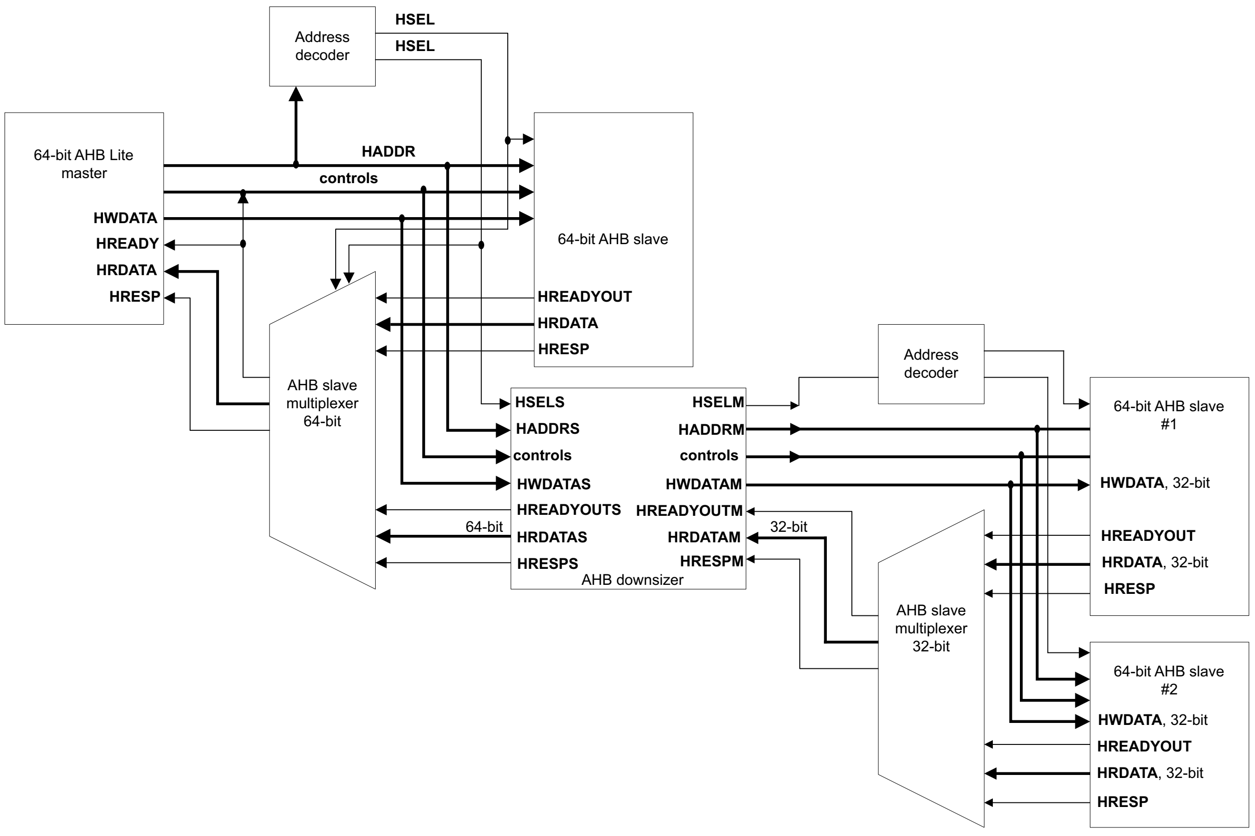


Figure 5-10 Using AHB downsizer, multiple connection

To maintain compatibility with the AHB downsizer in the *AMBA Design Kit* (ADK), the **HRESP** signals of AHB downsizer in Cortex-M System Design Kit are 2 bits wide. When using the AHB downsizer in an AHB Lite system, the bit one of the **HRESP** signal is not used as Figure 5-11 shows.

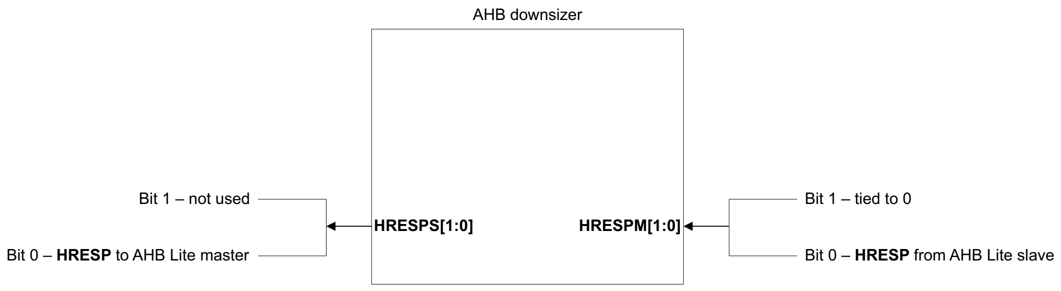


Figure 5-11 Using HRESP in AHB downsizer

5.4 AHB to APB asynchronous bridge

The following subsections describe the AHB to APB asynchronous bridge features and its operation:

- *Overview*
- *Cross-clock domain handling in AHB to APB asynchronous bridge* on page 5-27.

5.4.1 Overview

The AHB to APB asynchronous bridge, `ahb_to_apb_async.v`, supports APB2, APB3, and APB4. Figure 5-12 shows the AHB to APB asynchronous bridge module.

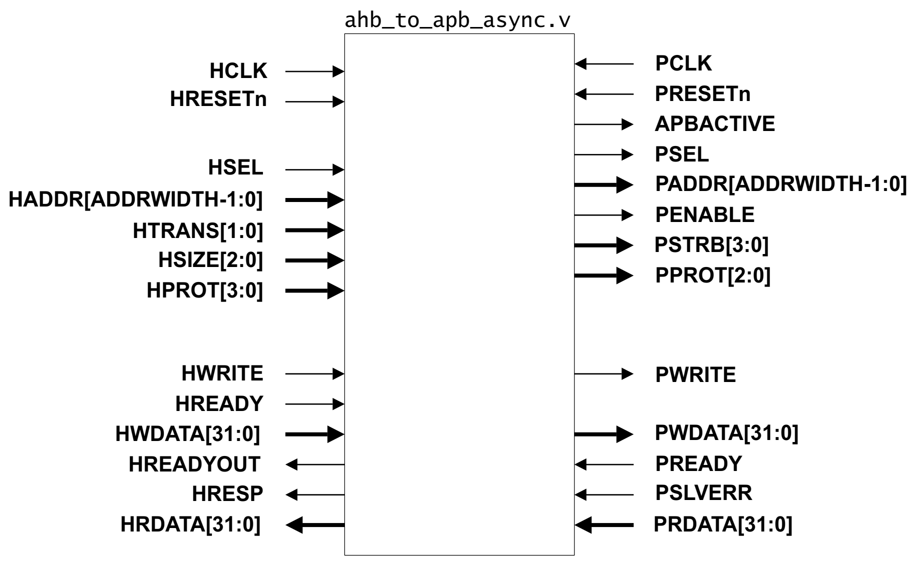


Figure 5-12 AHB to APB asynchronous bridge

Table 5-8 shows the characteristics of the AHB to APB asynchronous bridge.

Table 5-8 AHB to APB asynchronous bridge characteristics

Element name	Description	
Filename	`ahb_to_apb_async.v`	
Parameter	`ADDRWIDTH`	Width of the AHB or APB address bus. The default value is 16×(64Kbyte AHB or APB address space).
Clock domain	**HCLK** **PCLK**	

The AHB to APB bridge has an output called **APBACTIVE** which is used to control clock gating cell for generation of a gated **PCLK**.

The gated **PCLK** is called as **PCLKG** in the example system.

When there is no APB transfer, this signal is LOW and stops the **PCLKG**. The peripherals designed with separate clock pins for bus logic and peripheral operation can take advantage of the gated **PCLK** to reduce power consumption.

The **APBACTIVE** signal is generated in the APB clock domain.

For more information, see *AHB to APB sync-down bridge* on page 3-17.

5.4.2 Cross-clock domain handling in AHB to APB asynchronous bridge

Figure 5-13 shows the structure of the AHB to APB asynchronous bridge. The AHB to APB asynchronous bridge is divided into AHB clock domain and APB clock domain.

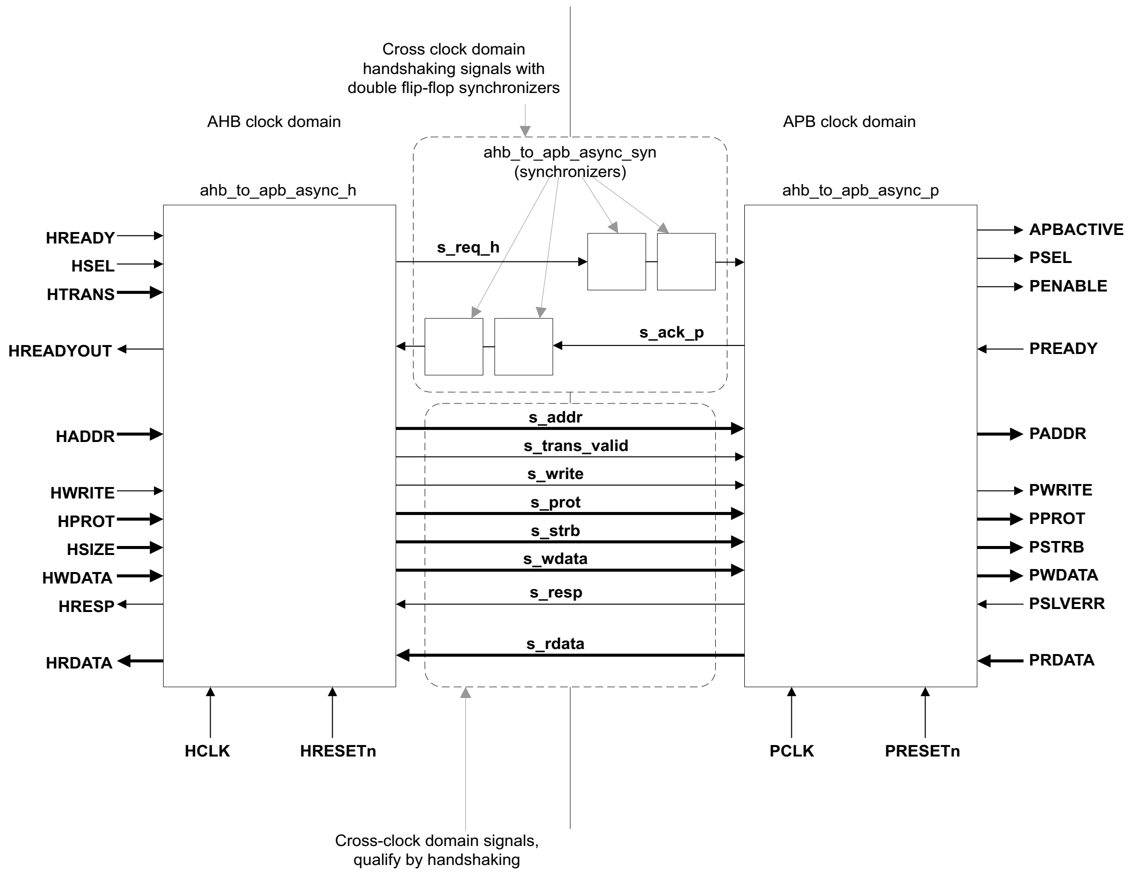


Figure 5-13 Structure of AHB to APB asynchronous bridge

If *Static Timing Analysis* (STA) is carried out, you can set the cross-clock domain signal path as false paths to avoid from being reported as timing violated paths.

5.5 AHB to AHB synchronous bridge

The following subsections describe the AHB to AHB synchronous bridge features and its operation:

- *Overview*
- *Using AHB to AHB synchronous bridge* on page 5-29.

5.5.1 Overview

The AHB to AHB synchronous bridge, `ahb_to_ahb_sync.v`, provides timing isolation in a large AHB system.

Figure 5-14 shows the AHB to AHB synchronous bridge.

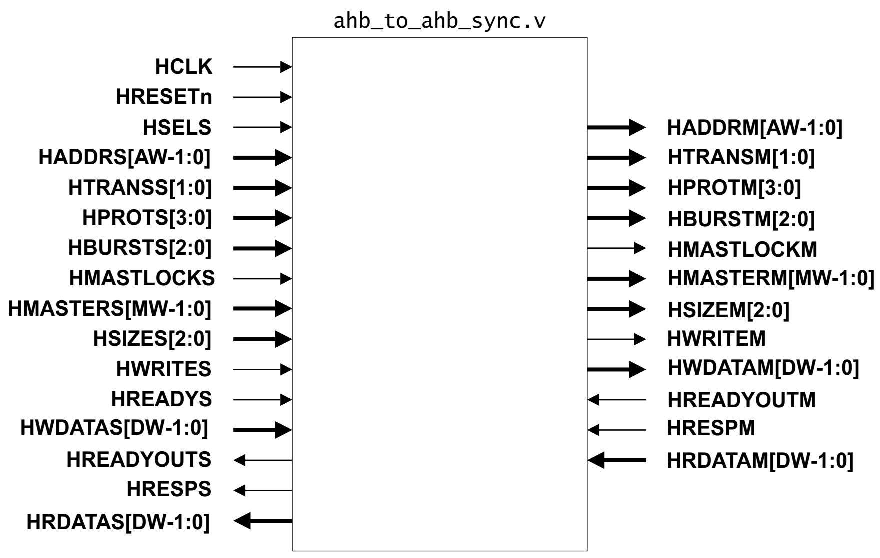


Figure 5-14 AHB to AHB synchronous bridge

Table 5-9 shows the characteristics of the AHB to AHB synchronous bridge.

Table 5-9 AHB to AHB synchronous bridge characteristics

Element name	Description
Filename	`ahb_to_ahb_sync.v`
Parameter	The parameters are as follows: `AW` Address width of the AHB address bus. This is set to 32 by default. `MW` Width of the **HMASTER** signal. This is set to 4 by default. `BURST` Set to: **0** Does not support burst by default. Burst transfers are converted to single transfers. **1** Burst support present. `DW` Data width. You can configure the width to either 64 bits or 32 bits. This is set to 32 by default.
Clock domain	**HCLK**

5.5.2 Using AHB to AHB synchronous bridge

Figure 5-15 shows the method to use the AHB to AHB synchronous bridge to isolate timing paths between two AHB segments.

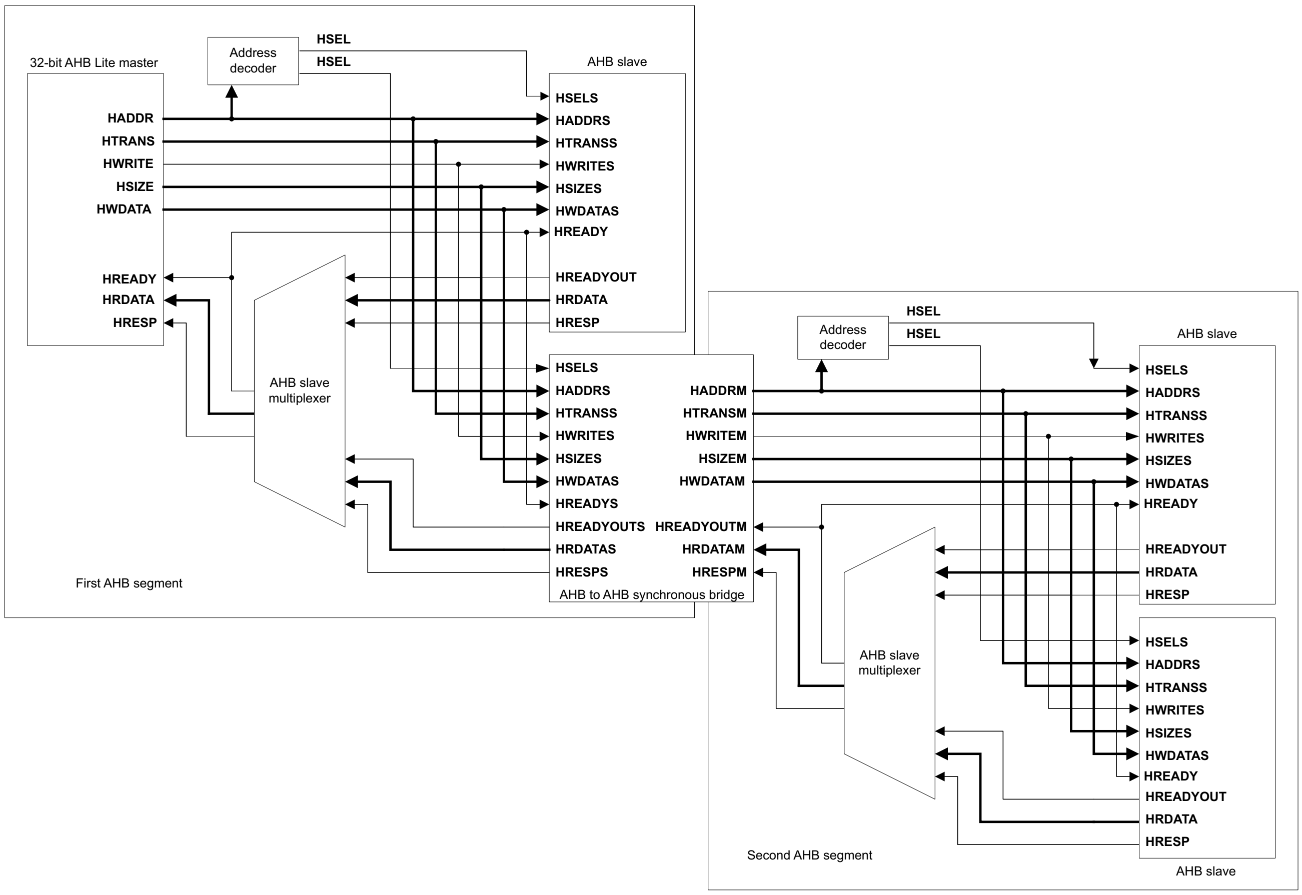


Figure 5-15 Using AHB to AHB synchronous bridge

The AHB to AHB synchronous bridge is useful for the designs with multiple FPGA when the AHB segment is divided into multiple devices. It registers both slave interface signals and master interface signals. When one direction registering is required, you can use either the AHB to AHB synchronous up or the AHB to AHB synchronous down bridge.

5.6 AHB to AHB sync-down bridge

The following subsections describe the AHB to AHB sync-down bridge features and its operation:

- *Overview*
- *Using the AHB to AHB sync-down bridge* on page 5-31
- *Optional write buffer* on page 5-32
- *Synthesizing the AHB to AHB sync-down bridge* on page 5-33.

5.6.1 Overview

The AHB to AHB sync-down bridge, `ahb_to_ahb_sync_down.v`, syncs-down the AHB domain from a higher frequency to a lower frequency if required. The supported features are as follows:

- optional write buffer that you can enable or disable using **HPROT[2]**
- registered address and control path
- unregistered feedback path, except error response case
- **BWERR** for Buffered Write Error, returned to the processor as an interrupt pulse
- optional burst support.

Figure 5-16 shows the AHB to AHB sync-down bridge.

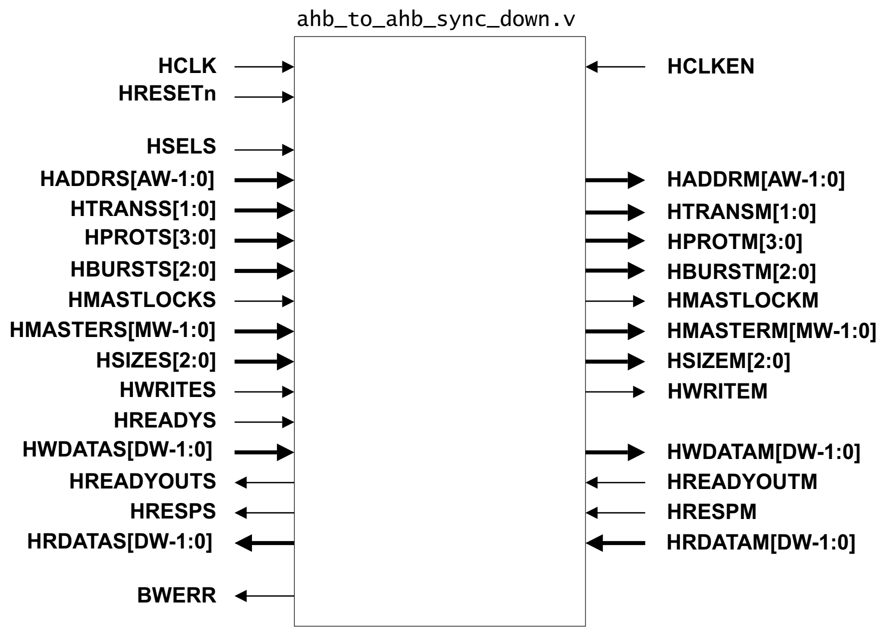


Figure 5-16 AHB to AHB sync-down bridge

You can configure this design as follows:

- if you set the `BURST` parameter to 0, burst transfers are converted into single transfers
- the **HCLK** signal of the slower AHB domain is divided from the **HCLK** of the faster AHB domain using **HCLKEN**.

Table 5-10 shows the characteristics of the AHB to AHB sync-down bridge.

Table 5-10 AHB to AHB sync-down bridge characteristics

Element name	Description	
Filename	`ahb_to_ahb_sync_down.v`	
Parameter	The parameters are as follows:	
	`AW`	Address width of the AHB address bus. This is set to 32 by default.
	`MW`	Width of the **HMASTER** signal. This is set to 1 by default.
	`DW`	Data width. You can configure the width to either 64 bits or 32 bits. This is set to 32 by default.
	`BURST`	When set to 0, burst transactions are converted into single transactions. When set to 1, burst transactions are supported. Removing burst support reduces the gate count. This is set to 0 by default.
	`WB`	Write buffer support. Set to 1 to include a single-level write buffer. Set to 0 to remove write buffer. This is set to 0 by default.
Clock domain	**HCLK**	

If a buffered write error occurs, it generates a single-cycle **BWERR** pulse in the fast **HCLK** domain.

5.6.2 Using the AHB to AHB sync-down bridge

The AHB to AHB sync-down bridge has a **HCLKEN** signal that is used to indicate the clock division between the fast AHB and the slow AHB. Figure 5-17 shows the clock divide operation for a 3 to 1 clock divide ratio.

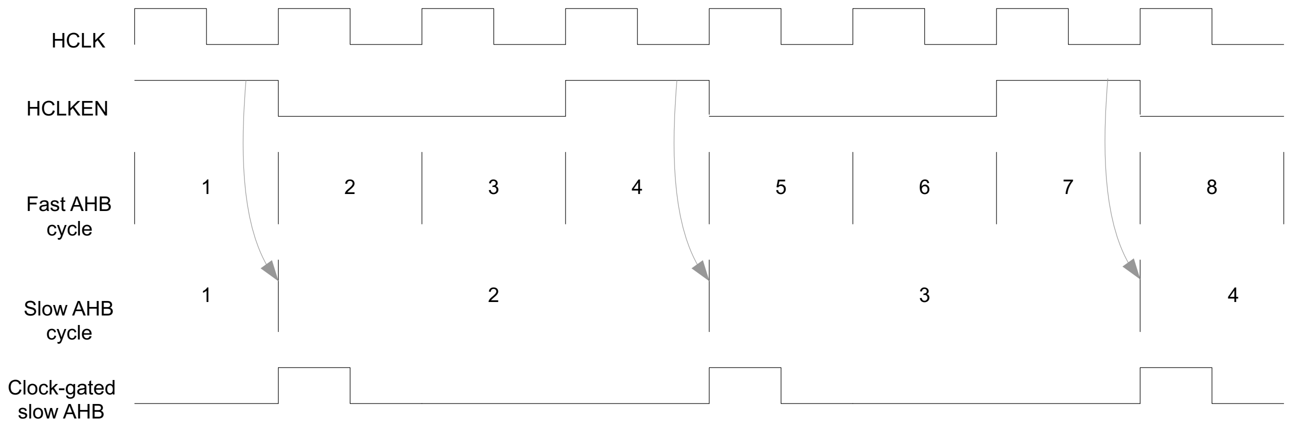


Figure 5-17 Clock divide operation

The **HCLKEN** must be synchronous to **HCLK**. It can be generated by a programmable counter. The slow AHB bus can use **HCLKEN** as a clock gating control to generate a clock-gated slow AHB which is used by the components connected to the slower AHB. See Figure 5-18 on page 5-32.

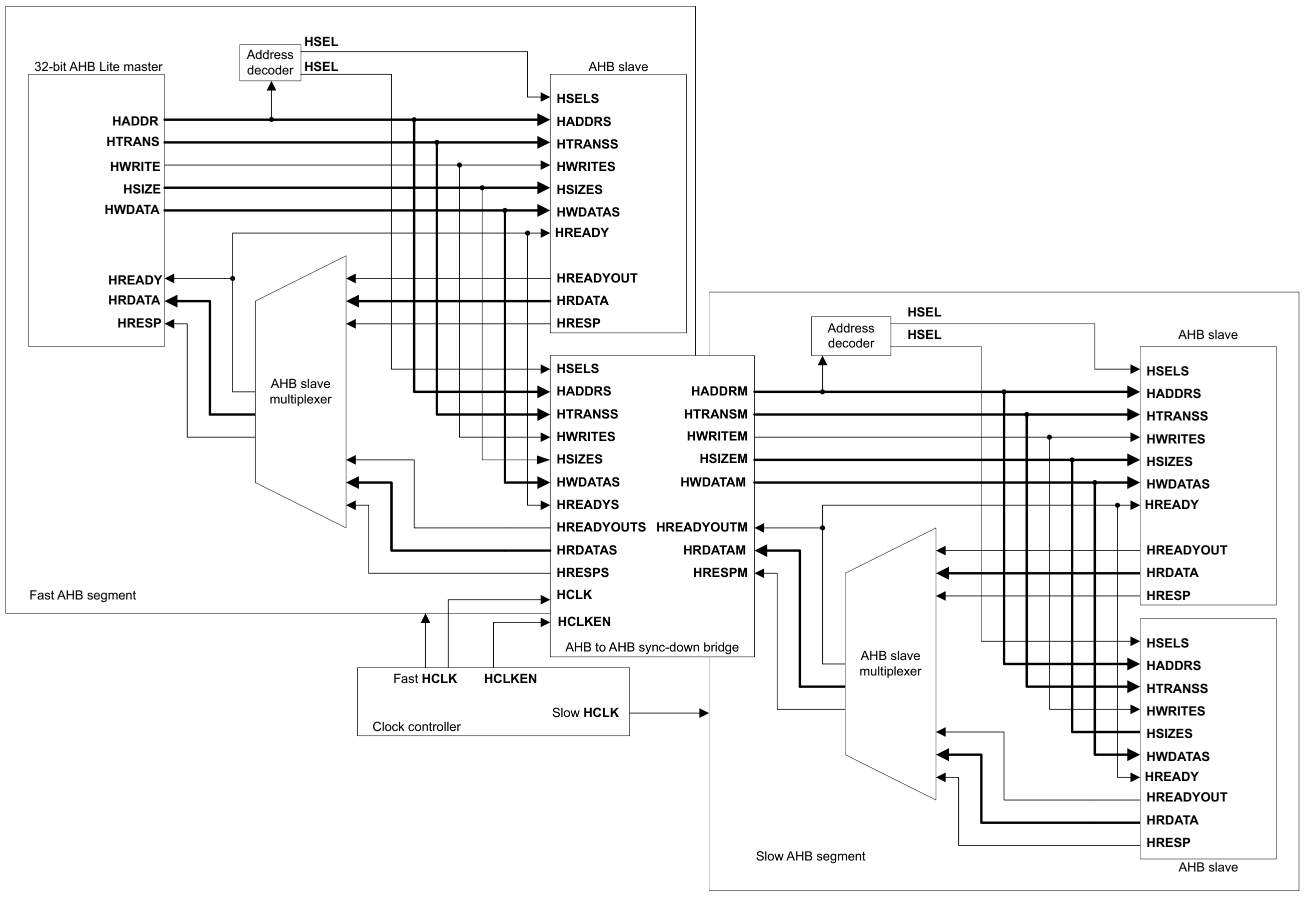


Figure 5-18 Using AHB to AHB sync-down bridge

If **HCLKEN** is tied HIGH, the two AHB segments have the same operation speed. However, the signals flowing from master to slave direction are registered so there is an additional latency cycle.

5.6.3 Optional write buffer

The optional write buffer of the AHB to AHB sync-down bridge can reduce the wait state, when writing a data to a peripheral or to a memory location in the slower clock domain. Without the write buffer, the bus master must wait till the transfer gets complete in the slower AHB. If the write buffer is present and the transfer is bufferable write, then the write buffer returns OKAY response to the bus master, and the actual write operation can be multi-cycle on the downstream AHB.

The write transfers with **HPROT[2]** set to HIGH are considered as bufferable, and the read transfers are considered as non-bufferable.

If the bus bridge is used for connecting peripherals, with some of the registers being non-bufferable, you can edit the top-level file of the bus bridge to include an address decoding logic to disable write buffering of these registers. For example, the peripheral registers for clearing interrupt request must be non-bufferable.

If the bus bridge is used in a multi-processor design with a bus level exclusive access monitor, exclusive stores must be handled as non-bufferable.

The optional write buffer is one-level deep. If the bus master issue another transfer to the same AHB segment while the previous buffer write is on-going, then the transfer request is reserved on hold in the write buffer, and wait state is inserted. When the downstream AHB completes the previous transfer, the held transfers are sent to the downstream AHB. If the held transfer is a bufferable write, then the write buffer returns OKAY response to the AHB master issuing the transfer.

5.6.4 Synthesizing the AHB to AHB sync-down bridge

The AHB to AHB sync-down bridge contains combinational paths from the slow AHB domain to the fast AHB domain because of the unregistered feedback path feature. These signals include **HRDATA**, and **HREADYOUT**. The unregistered feedback path permits lower access latency, but few precautions are required when synthesizing the system.

The following precautions are required during the system synthesis:

- The synthesis of the AHB to AHB sync-down bridge is targeted at the frequency of the faster AHB. The design has only one **HCLK** input, so you must connect the input to the fast AHB clock signal.
- If the synthesis of the slow AHB and the fast AHB system are carried out separately, the timing constraints of the signals from the slow AHB to the bridge are controlled properly to prevent timing violation.

For example, when synthesizing the slow clock domain logic, if the synthesis process is partitioned into fast clock domain and slow clock domain, then you must setup the timing constraints of the read data signal, **HRDATA** based on the overall timing path. See Figure 5-19.

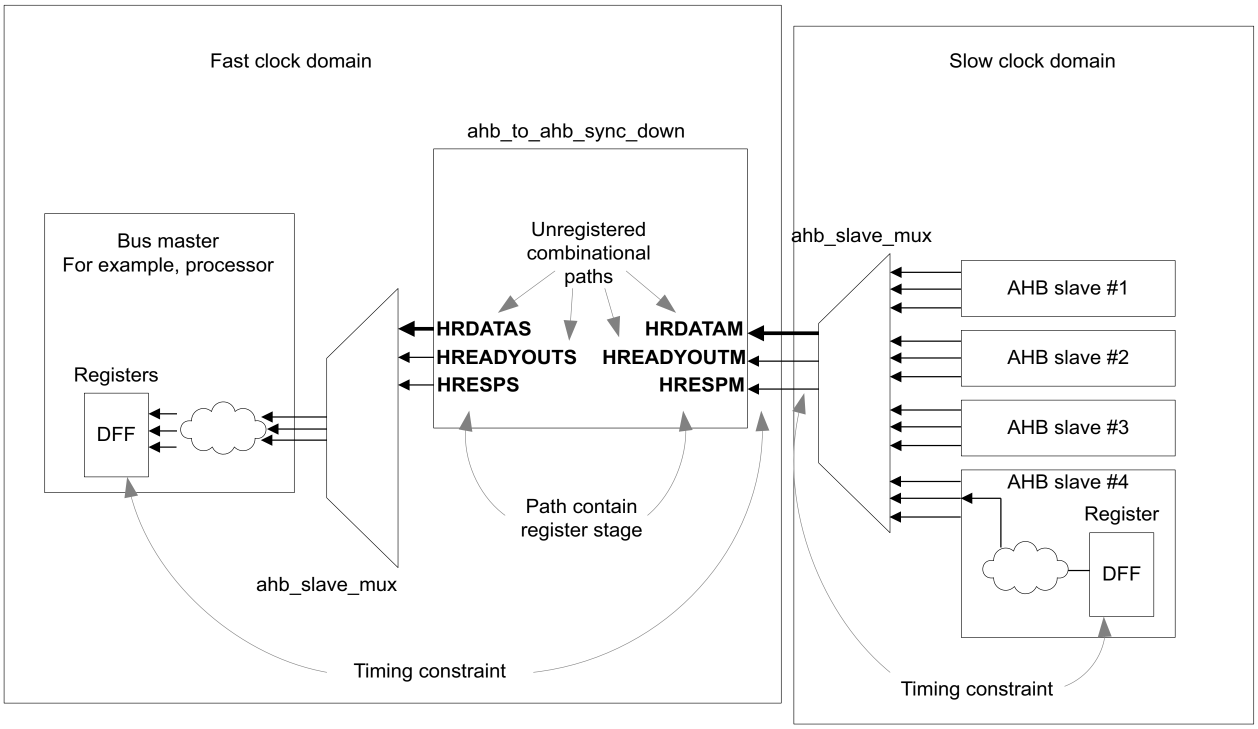


Figure 5-19 Synthesizing the AHB to AHB sync-down bridge

The simplest arrangement is to restrict the whole path to just one fast **HCLK** cycle. If it is not possible, you can use multi-cycle path, and might require masking the **HRDATAS** output from the ahb_to_ahb_sync_down bridge to 0, when **HREADYOUTS** is LOW to prevent metastability issue.

Similar handling is required for the **HREADYOUT** and **HRESP** from the slow clock domain. There is an unregistered combinational path for the **HREADYOUT** connection in the AHB to AHB sync-down bridge. The **HRESPS** output from bridge is generated from registered logic within the bridge, but timing constraints are still required to ensure that there is no timing violation from **HRESP** source in the slow clock domain to the registers within the AHB to AHB sync-down bridge.

5.7 AHB to AHB sync-up bridge

The following subsections describe the AHB to AHB sync-down bridge features and its operation:

- *Overview*
- *Using the AHB to AHB sync-up bridge* on page 5-36
- *Synthesizing the AHB to AHB sync-up bridge* on page 5-37.

5.7.1 Overview

The AHB to AHB sync-up bridge, `ahb_to_ahb_sync_up.v`, enables you to sync-up the AHB from a lower frequency to a higher frequency if required. The supported features are as follows:

- optional write buffer, you can enable or disable the buffering using **HPROT[2]**
- unregistered address and control path
- registered feedback path
- **BWERR** for Buffered Write Error, return to processor as interrupt pulse
- optional burst support.

Figure 5-20 shows the AHB to AHB sync-up bridge module.

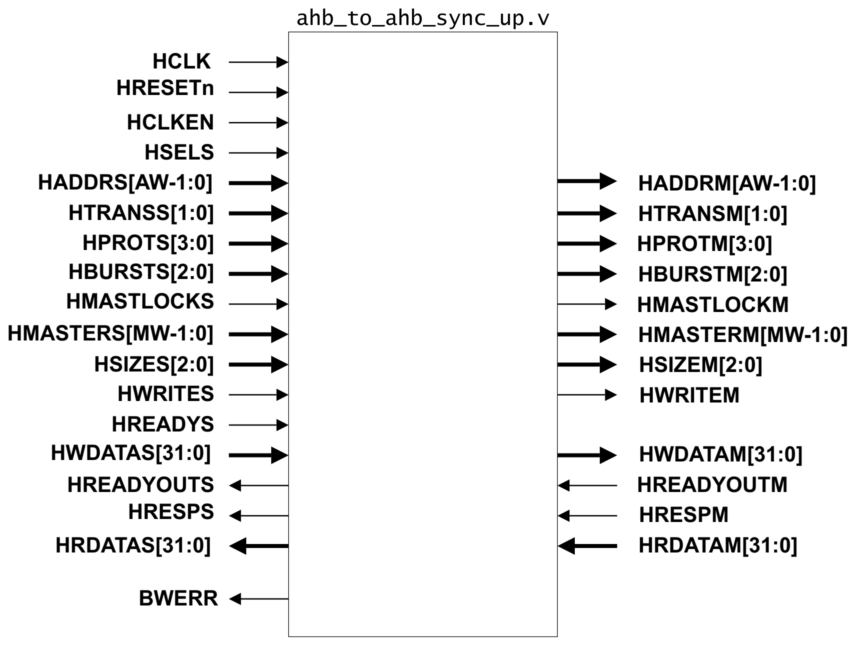


Figure 5-20 AHB to AHB sync-up bridge

You can configure this design as follows:

- if you set the `BURST` parameter to 0, the burst transfers are converted into single transfers
- the **HCLK** signal of the slower AHB domain is divided from the **HCLK** of the faster AHB domain using **HCLKEN**.

Table 5-11 shows the characteristics of the AHB to AHB sync-up bridge.

Table 5-11 AHB to AHB sync-up bridge characteristics

Element name	Description	
Filename	`ahb_to_ahb_sync_up.v`	
Parameter	The parameters are as follows:	
	`AW`	Address width of the AHB address bus. This is set to 32 by default.
	`MW`	Width of the **HMASTER** signal. This is set to 1 by default.
	`DW`	Data width. You can configure the width to either 64 bits or 32 bits. This is set to 32 by default.
	`BURST`	When set to 0, burst transactions are converted into single transactions. When set to 1, burst transactions are supported. Removing burst support reduces the gate count. This is set to 0 by default.
	`WB`	Write buffer support. Set to 1 to include a single-level write buffer. Set to 0 to remove write buffer. This is set to 0 by default.
Clock domain	**HCLK**	

If a buffered write error occurs, it generates a single-cycle pulse **BWERR** in the fast **HCLK** domain. For more information on the optional write buffer, see *Optional write buffer* on page 5-32.

5.7.2 Using the AHB to AHB sync-up bridge

The AHB to AHB sync-up bridge has a **HCLKEN** signal which is used to indicate the clock division between the fast AHB and the slow AHB. Figure 5-21 shows the clock divide operation for a 3-1 clock divide ratio.

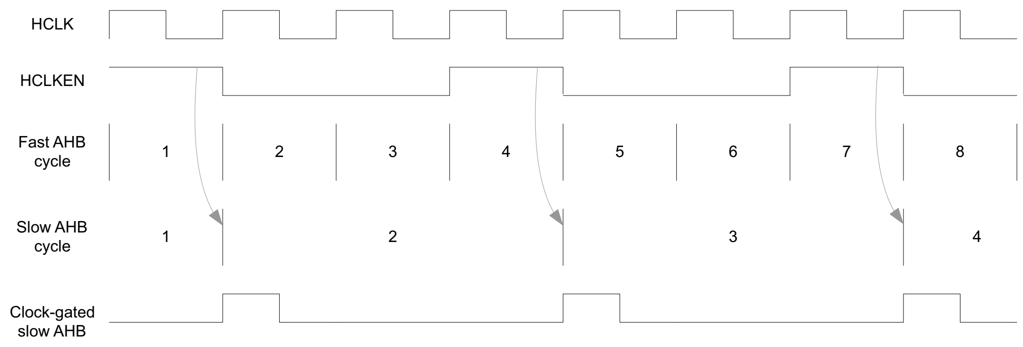


Figure 5-21 Clock divide operation

The **HCLKEN** must be synchronous to **HCLK**. It can be generated by a programmable counter. The slow AHB bus can use **HCLKEN** as a clock gating control to generate a clock-gated slow AHB which is used by the components connected to the slower AHB.

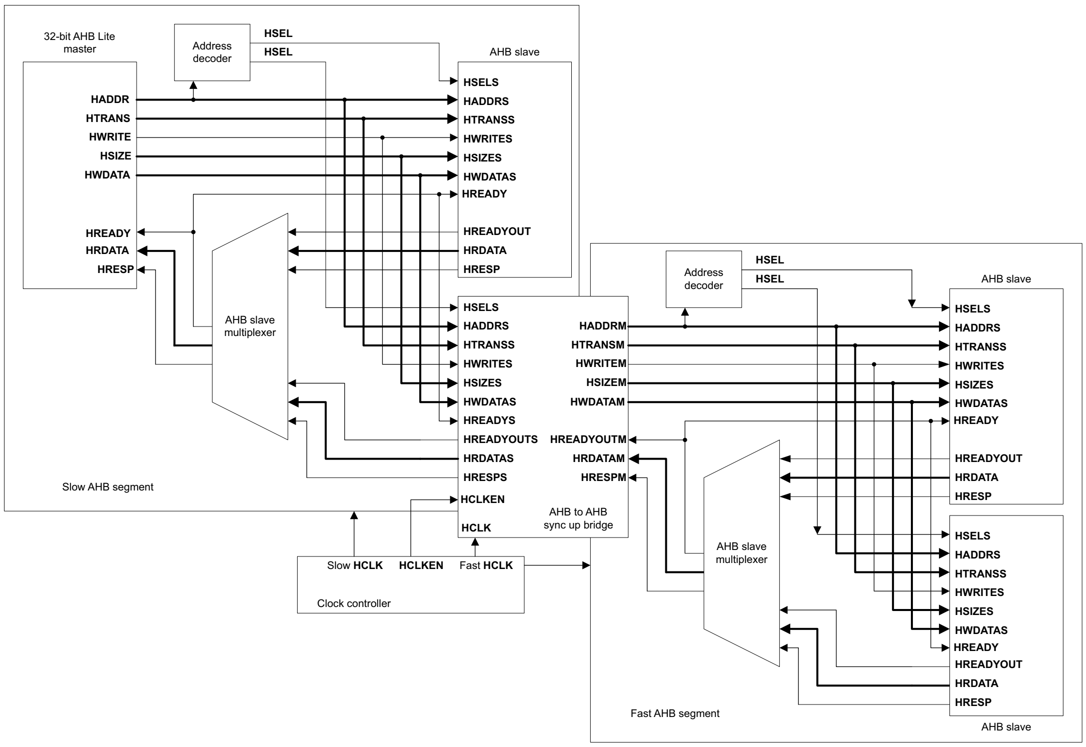


Figure 5-22 Using AHB to AHB sync-up bridge

If **HCLKEN** is tied HIGH, then the two AHB segments have the same operation speed. However, the signals flowing from slaves to master direction are registered so there is an additional latency cycle.

For more information on write buffer option, see *Optional write buffer* on page 5-32.

5.7.3 Synthesizing the AHB to AHB sync-up bridge

The AHB to AHB sync-up bridge contains combinational address, and control paths from the slow AHB domain to the fast AHB domain. These signals include **HADDRM**, **HTRANSM**, **HSIZEM**, **HWRITEM**, **HPROTM**, **HMASTERM**, **HMASTLOCKM**, and **HWDATAM**. The unregistered paths permits lower access latency, but few precautions are required when synthesizing the system. See *Synthesizing the AHB to AHB sync-down bridge* on page 5-33 for precautions.

For example, if the synthesis process is partitioned into fast clock domain and slow clock domain, when synthesizing the slow clock domain logic, you must setup the timing constraints of these signals based on the overall timing path so that they will not cause timing violation in the fast clock domain as Figure 5-23 on page 5-38 shows.

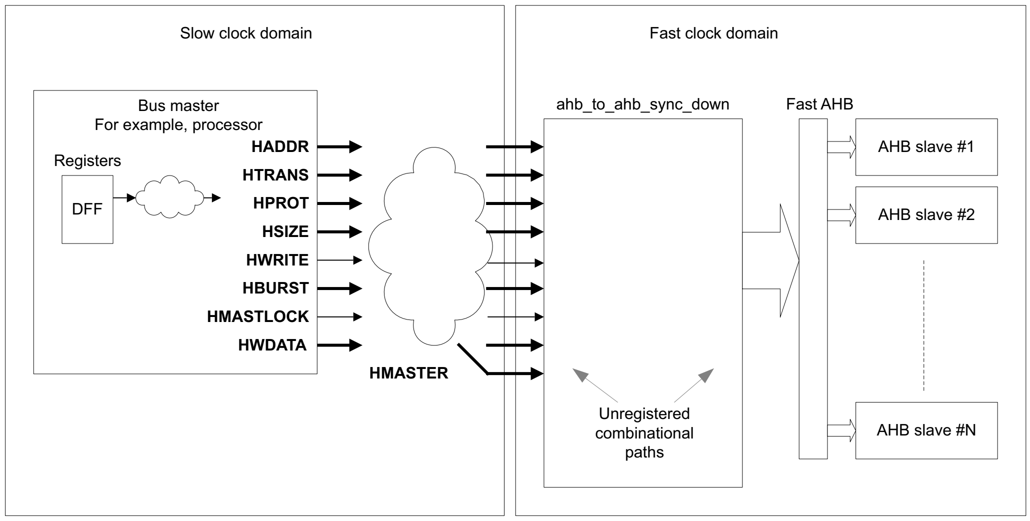


Figure 5-23 Combinational paths from slow AHB to fast AHB

Chapter 6
Behavioral Memory Models

This chapter describes the behavioral models in the Cortex-M System Design Kit. It contains the following sections:

6.1 ROM model wrapper

The AHB ROM wrapper model, `ahb_rom.v`, permits easy switching between the following implementations of ROM:

- behavioral ROM model, using behavioral SRAM with write disabled
- flash wrapper with simple 32-bit flash memory
- SRAM model with an AHB SRAM interface module, suitable for FPGA flow, and permitting read and write operations
- none.

Table 6-1 shows the characteristics of the ROM model wrapper.

Table 6-1 ROM model wrapper characteristics

Element name	Description
Filename	`ahb_rom.v`
Parameters	The parameters are as follows: `MEM_TYPE` The `MEM_TYPE` value ranges from 0 to 3. See Table 6-2. `AW` Address width. The default value is 16. `filename` File name for memory image. `WS_N` First access or NONSEQUENTIAL access wait state. The default value is 0. `WS_S` Sequential access wait state. The default value is 0. `BE` Big-endian. The default value is 0, little-endian. Set the value to 1 for big-endian configuration. **Note** This parameter is a placeholder to permit the possibility of propagating endian configuration to a specific memory implementation. Currently, it is not used by existing memory implementations provided that this design kit provides.
Clock domain	**HCLK**

Table 6-2 shows the configuration of the `ahb_rom.v`, that a `MEM_TYPE` Verilog parameter defines.

Table 6-2 Configuration of `ahb_rom.v`

MEM_TYPE	Design of `ahb_rom.v`	Configurability
`AHB_ROM_NONE`	See Figure 6-1 on page 6-3	None.

Table 6-2 Configuration of ahb_rom.v (continued)

MEM_TYPE	Design of ahb_rom.v	Configurability	
AHB_ROM_BEH_MODEL	See Figure 6-2 on page 6-4	AW	Address width.
		filename	File name for memory image.
		WS_N	First access or NONSEQUENTIAL access wait state.
		WS_S	Sequential access wait state.
AHB_ROM_FPGA_SRAM_MODEL	See Figure 6-3 on page 6-4	AW	Address width.
		filename	File name for memory image.
		Note Always in zero wait state.	
AHB_ROM_FLASH32_MODEL	See Figure 6-4 on page 6-5	AW	Address width.
		filename	File name for memory image.
		WS_N	First access or NONSEQUENTIAL access wait state.

A Verilog parameter, MEM_TYPE defines the configuration of the ahb_rom.v.

Figure 6-1 shows the design of ahb_rom.v for AHB_ROM_NONE.

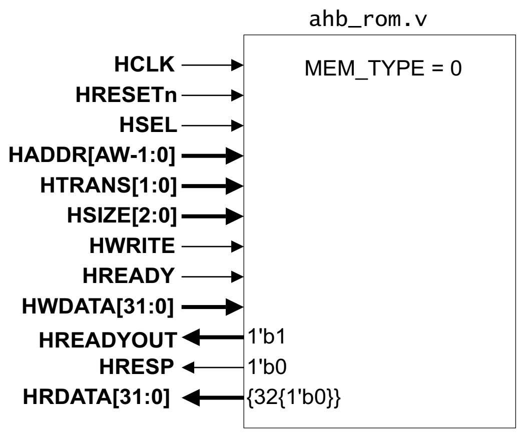


Figure 6-1 Design of ahb_rom.v for AHB_ROM_NONE

Figure 6-2 on page 6-4 shows the design of ahb_rom.v for AHB_ROM_BEH_MODEL.

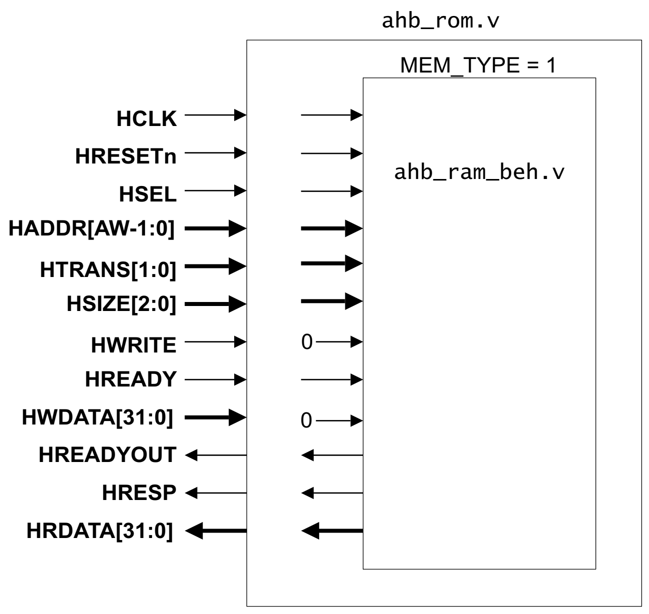


Figure 6-2 Design of `ahb_rom.v` **for** `AHB_ROM_BEH_MODEL`

Figure 6-3 shows the design of `ahb_rom.v` for `AHB_ROM_FPGA_SRAM_MODEL`.

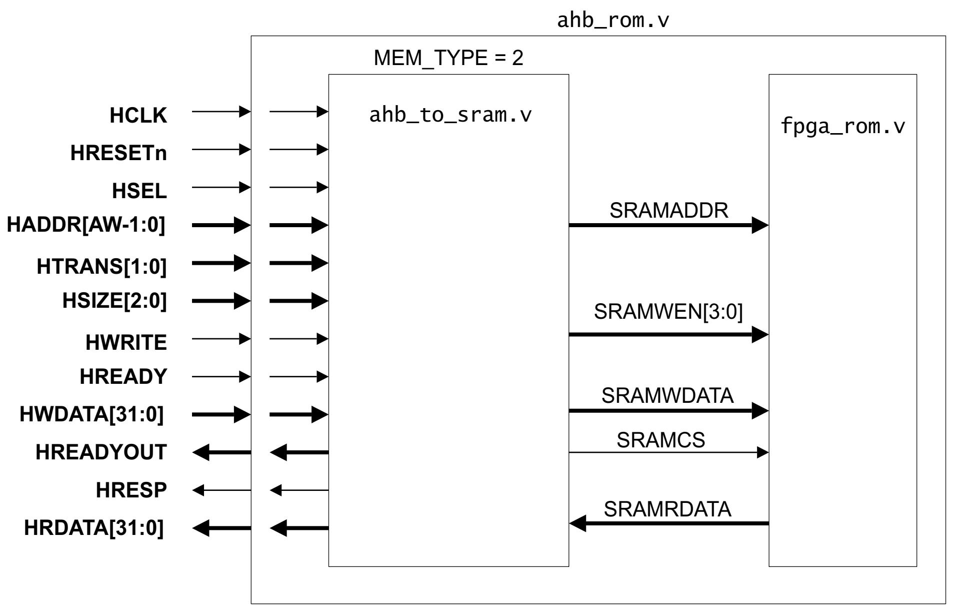


Figure 6-3 Design of `ahb_rom.v` **for** `AHB_ROM_FPGA_SRAM_MODEL`

Figure 6-4 on page 6-5 shows the design of `ahb_rom.v` for `AHB_ROM_FLASH32_MODEL`.

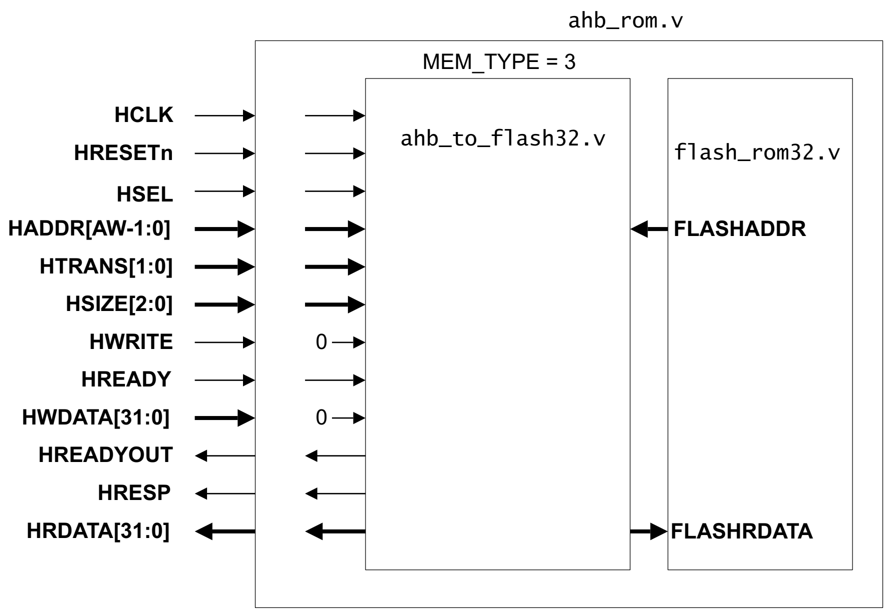


Figure 6-4 Design of `ahb_rom.v` **for** `AHB_ROM_FLASH32_MODEL`

6.2 RAM model wrapper

An AHB RAM wrapper model, `ahb_ram.v`, permits easy switching between the following implementations of RAM:

- behavioral RAM model
- SRAM model with an AHB SRAM interface module, suitable for ASIC or FPGA flow.

Table 6-3 shows the characteristics of the RAM model wrapper.

Table 6-3 RAM model wrapper characteristics

Element name	Description	
Filename	`ahb_ram.v`	
Parameter	The parameters are as follows:	
	`MEM_TYPE`	See Table 6-4.
	`AW`	Width of the address bus. The default value is 16.
	`filename`	File name for memory image.
	`WS_N`	First access or NONSEQUENTIAL access wait state. The default value is 0.
	`WS_S`	Sequential access wait state. The default value is 0.
	`BE`	Big-endian. The default value is 0, little-endian. Set the value to 1 for big-endian configuration.
Clock domain	**HCLK**	

Table 6-4 shows the configuration of `ahb_ram.v,` that a `MEM_TYPE` Verilog parameter defines.

Table 6-4 Configuration of `ahb_ram.v`

MEM_TYPE	Design of `ahb_rom.v`	Configurability	
`AHB_RAM_NONE`	See Figure 6-5 on page 6-7	None	
`AHB_RAM_BEH_MODEL`	See Figure 6-6 on page 6-7	`AW`	Address width.
		`filename`	File name for memory image.
		`WS_N`	First access or NONSEQUENTIAL access wait state.
		`WS_S`	Sequential access wait state.
`AHB_RAM_FPGA_SRAM_MODEL`	See Figure 6-7 on page 6-8	`AW`	Address width.
		`filename`	File name for memory image.
		Note Always in zero wait state.	
`AHB_RAM_EXT_SRAM16_MODEL`	See Figure 6-8 on page 6-8	`AW`	Address width.
		`WS_N`	Additional wait state for read, write, and turnaround cycle.
`AHB_RAM_EXT_SRAM8_MODEL`	See Figure 6-9 on page 6-9	`AW`	Address width.
		`WS_N`	Additional wait state for read, write, and turnaround cycle.

A Verilog parameter, `MEM_TYPE` defines the configuration of the `ahb_rom.v`.

Figure 6-5 on page 6-7 shows the design of `ahb_ram.v` for `AHB_RAM_NONE`.

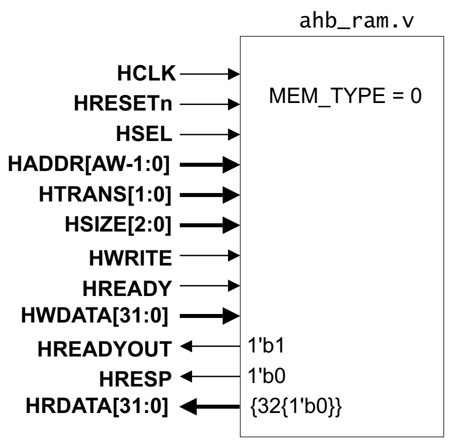


Figure 6-5 Design of `ahb_ram.v` **for** `AHB_RAM_NONE`

Figure 6-6 shows the design of `ahb_ram.v` for `AHB_RAM_BEH_MODEL`.

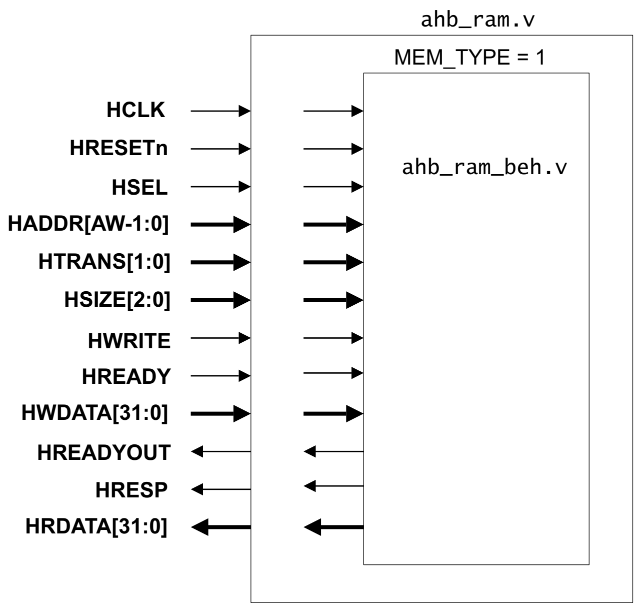


Figure 6-6 Design of `ahb_ram.v` **for AHB_RAM_BEH_MODEL**

Figure 6-7 on page 6-8 shows the design of `ahb_ram.v` for `AHB_FPGA_SRAM_MODEL`.

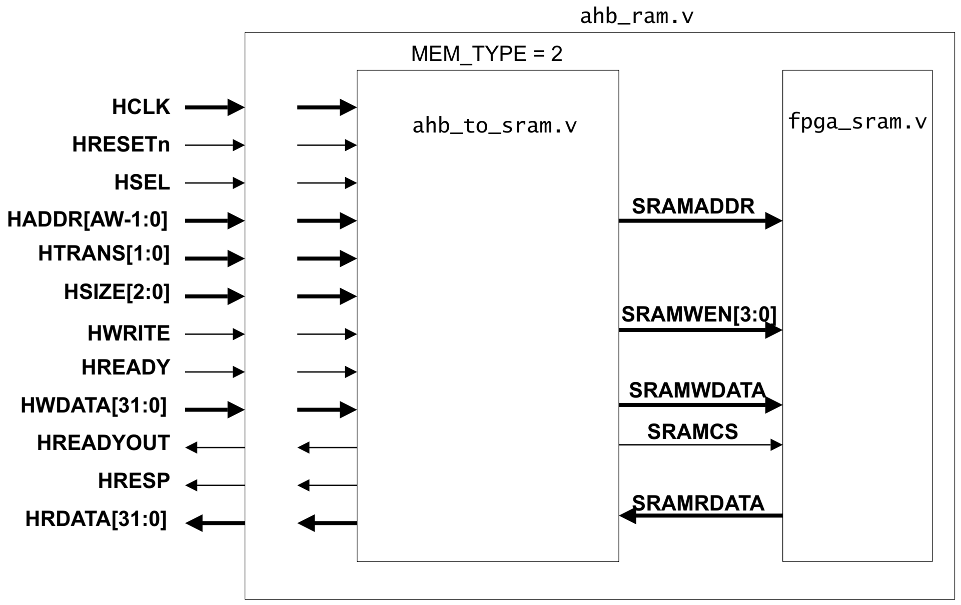


Figure 6-7 Design of `ahb_ram.v` for `AHB_RAM_FPGA_SRAM_MODEL`

Figure 6-8 shows the design of `ahb_ram.v` for `AHB_RAM_EXT_SRAM16_MODEL`.

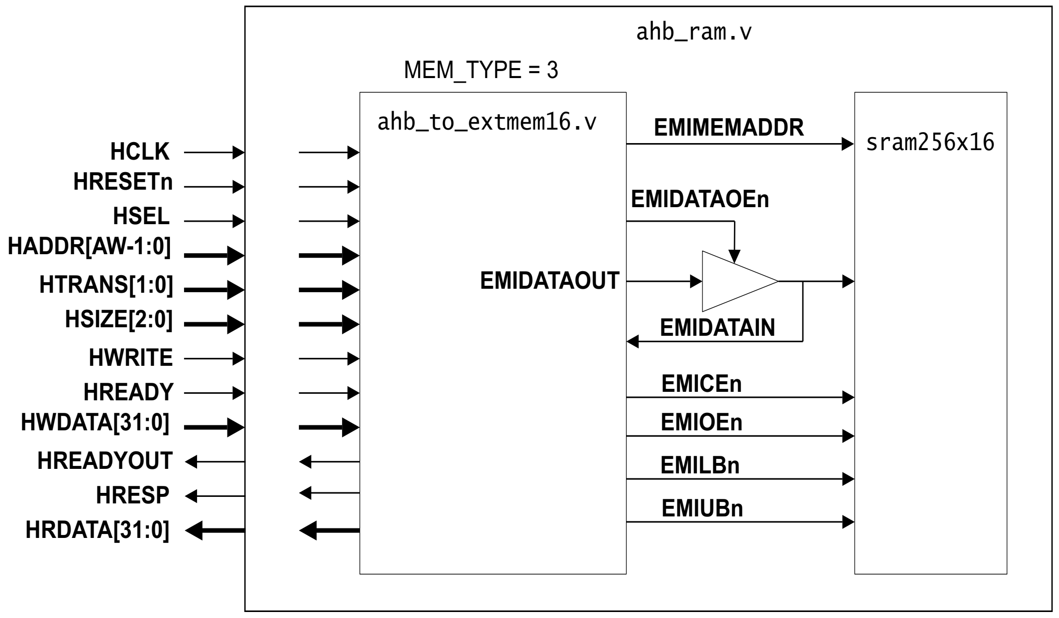


Figure 6-8 Design of `ahb_ram.v` for `AHB_RAM_EXT_SRAM16_MODEL`

Figure 6-9 on page 6-9 shows the design of `ahb_ram.v` for `AHB_RAM_EXT_SRAM8_MODEL`.

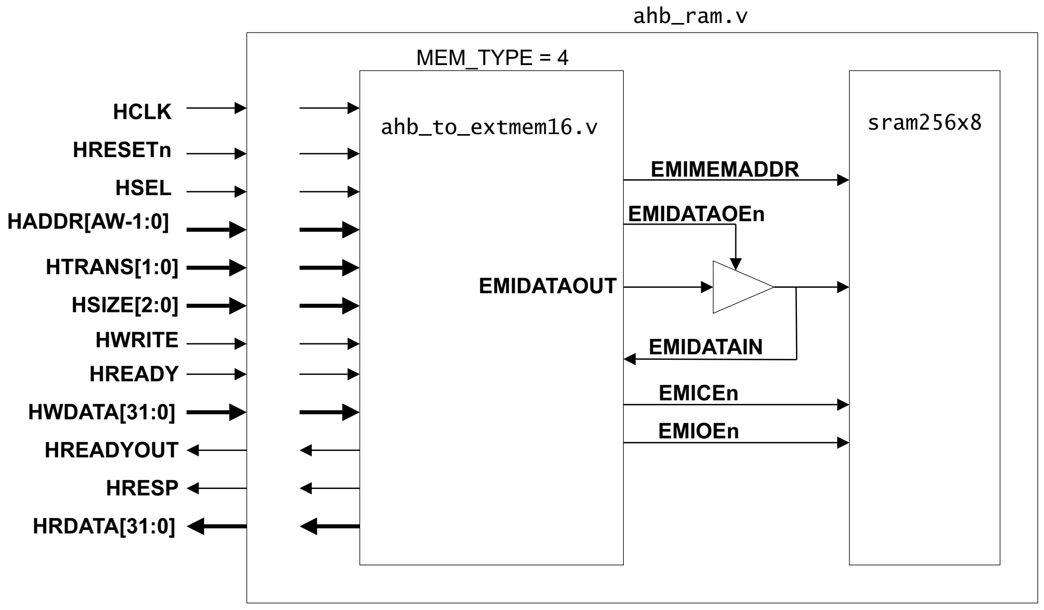


Figure 6-9 Design of `ahb_ram.v` **for** `AHB_RAM_EXT_SRAM8_MODEL`

The `AHB_RAM_EXT_SRAM16_MODEL` and `AHB_RAM_EXT_SRAM8_MODEL` options are not illustrations of real system designs. The external memory interface module, `ahb_to_extmem16`, normally connects to off-chip memory. In the case of `ahb_ram.v`, these configuration options permit you to perform benchmarking with your own external memory model.

6.3 Behavioral SRAM model with AHB interface

The behavioral AHB SRAM model, `ahb_ram_beh.v`, enables you to define an initial memory image and generate wait states for both NONSEQUENTIAL and SEQUENTIAL transfers. The model always replies with an OKAY response. Figure 6-10 shows the behavioral SRAM model with AHB interface.

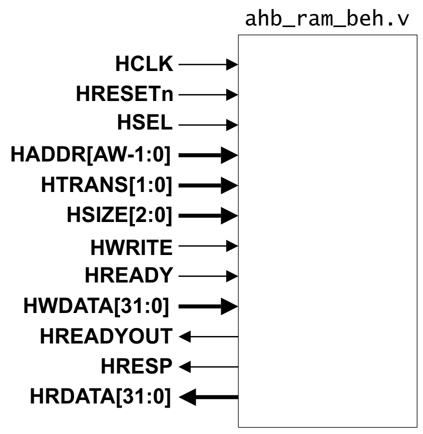


Figure 6-10 Behavioral SRAM model with AHB interface

Table 6-5 shows the characteristics of the behavioral SRAM model with an AHB interface.

Table 6-5 Behavioral SRAM model with an AHB interface characteristics

Element name	Description	
Filename	`ahb_ram_beh.v`	
Parameter	The parameters are as follows:	
	`AW`	Address width. The default value is 16.
	`filename`	File name for memory image.
	`WS_N`	First access or NONSEQUENTIAL access wait state. The default value is 0.
	`WS_S`	Sequential access wait state. The default value is 0.
Clock domain	**HCLK**	

6.4 32-bit flash ROM behavioral model

This is a simple behavioral model for 32 bits flash memory. Reset and clock signals perform wait state behavioral modeling. Figure 6-11 shows the 32 bits flash ROM behavioral model.

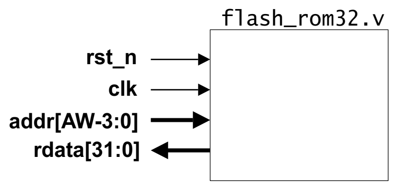


Figure 6-11 32 bits flash ROM behavioral model

Table 6-6 shows the characteristics of the 32 bits flash ROM behavioral model.

Table 6-6 32 bits flash ROM behavioral model characteristics

Element name	Description
Filename	`flashh_rom32.v`
Parameter	The parameters are as follows: `AW` Width of address bus. The default value is 16. `filename` File name for memory image. `WS` Wait state or required read cycle. The default value is 0.
Clock domain	**CLK**. In the example system provided, **CLK** is the same as **HCLK**. **Note** The connections for clocks and resets are for the wait state modeling.

6.4.1 Signal descriptions

Table 6-7 shows the signal descriptions of the 32 bits flash ROM behavioral model.

Table 6-7 32 bits flash ROM behavioral model signals

Signal	Type	Description
ADDR[AW-3:0]	Input	Address. The default value is 16.
RDATA[31:0]	Output	Read data.

6.5 SRAM synthesizable model

This is a model for SRAM that behaves like simple synchronous RAM in ASIC or FPGA. This memory does not have an AHB interface, and the AHB to SRAM interface module is required to connect this memory to AHB. It demonstrates how to use the AHB to SRAM interface module. This model is suitable for FPGA synthesis. Figure 6-12 shows the SRAM synthesizable model.

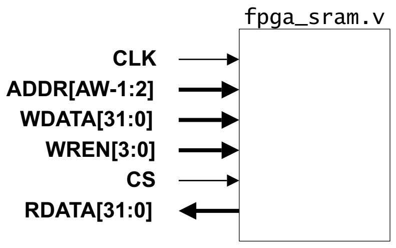


Figure 6-12 FPGA SRAM

Table 6-8 shows the characteristics of the FPGA SRAM model.

Table 6-8 FPGA SRAM characteristics

Element name	Description	
Filename	`fpga_sram.v`	
Parameter	`AW`	Address width. The default value is 16.
Clock domain	**CLK**	

6.6 FPGA ROM

The FPGA ROM, `fpga_rom.v`, is a model that behaves like a simple synchronous RAM in FPGA. This memory does not have an AHB interface, and the AHB to SRAM interface module is required to connect this memory to AHB. It demonstrates how to use the AHB to SRAM interface module. This module is suitable for FPGA synthesis. Unlike the FPGA SRAM model, this model contains initialization of memory. Figure 6-13 shows the FPGA ROM model.

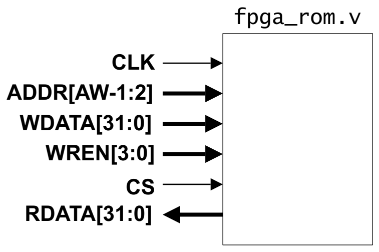


Figure 6-13 FPGA ROM

Table 6-9 shows the characteristics of the FPGA ROM.

Table 6-9 FPGA ROM characteristics

Element name	Description
Filename	`fpga_rom.v`
Parameter	The parameters are as follows: `AW` Address width. `filename` File name for memory image.
Clock domain	**CLK**. In the example system provided, **CLK** is same as **HCLK**.

6.6.1 Signal descriptions

Table 6-10 shows the signal descriptions for the FPGA ROM.

Table 6-10 FPGA ROM signals

Signal	Type	Description
ADDR[AW-1:2]	Input	Address
WDATA[31:0]	Input	Write data
WREN[3:0]	Input	Write enable
CS	Input	Chip select
RDATA[31:0]	Output	Read data

6.7 External asynchronous 8 bits SRAM

This is a behavioral model for external 8 bits SRAM that behaves like a typical asynchronous SRAM component. This memory model is compatible with the AHB to external memory interface. Figure 6-14 shows the external asynchronous 8 bits SRAM.

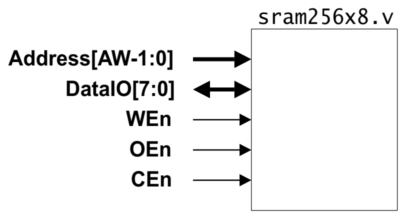


Figure 6-14 External asynchronous 8 bits SRAM

Table 6-11 shows the external asynchronous 8 bits SRAM characteristics.

Table 6-11 External asynchronous 8 bits SRAM characteristics

Element name	Description
Filename	`sram256x8.v`
Parameter	The parameters are as follows: `AW` Address width. The default value is 18. `filename` File name for initial SRAM content. Default to `NULL` that means no initial memory image.
Clock domain	Not Applicable.

6.7.1 Signal descriptions

Table 6-12 shows the signal descriptions for the external asynchronous 8 bits SRAM.

Table 6-12 External asynchronous 8 bits SRAM signals

Signal	Type	Description
ADDR[AW-1:0]	Input	Address.
DATAIO[7:0]	Bidirectional	Data.
WEn	Input	Write enable. Active LOW for write operation.
OEn	Input	Output enable. Active LOW for read operations.
CEn	Input	Chip enable. Active LOW for both read and write operations.

6.8 External asynchronous 16-bit SRAM

This is a behavioral model for external 16 bits SRAM that behaves like a typical asynchronous SRAM component. This memory model is compatible with the AHB to external memory interface. Figure 6-15 shows the external asynchronous 16 bits SRAM.

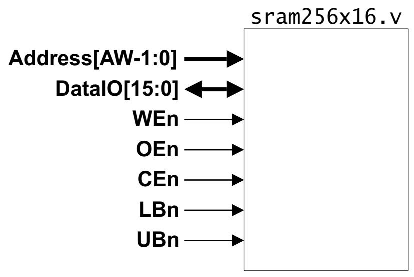


Figure 6-15 External asynchronous 16 bits SRAM

Table 6-13 shows the external asynchronous 16 bits SRAM characteristics.

Table 6-13 External asynchronous 16 bits SRAM characteristics

Element name	Description
Filename	`sram256x16.v`
Parameter	The parameters are as follows: `AW` Address width. The default value is 18. `filename` File name for initial SRAM content. The default is `NULL` and this means no initial memory image.
Clock domain	Not Applicable.

6.8.1 Signal descriptions

Table 6-14 shows the signal descriptions for external asynchronous 16 bits SRAM

Table 6-14 External asynchronous 16-bit SRAM signals

Signal	Type	Description
ADDR[AW-1:0]	Input	Address.
DATAIO[15:0]	Bidirectional	Data.
WEn	Input	Write enable. Active LOW for write operation.
OEn	Input	Output enable. Active LOW for read operations.
CEn	Input	Chip enable. Active LOW for both read and write operations.
LBn	Input	Lower byte enable. Active LOW.
UBn	Input	Upper byte enable. Active LOW.

Chapter 7
Verification Components

This chapter describes the verification components in the Cortex-M System Design Kit. It contains the following sections:

7.1 AHB protocol checker

The AHB protocol checker, `AhbPC.v`, is a simulation model that you can use to detect bus protocol violations during simulation. The design is based on the OVL. To use the AHB protocol checker, you must download the OVL Verilog library from Accellera, and add the OVL library path in the include and search paths of your simulator setup.

In normal usage scenarios, the AHB protocol checker can be instantiated within a system conditionally to monitor the activities of an AHB. Use of conditional compilation is necessary because the AHB protocol checker is not a synthesizable component. Figure 7-1 shows the AHB protocol checker.

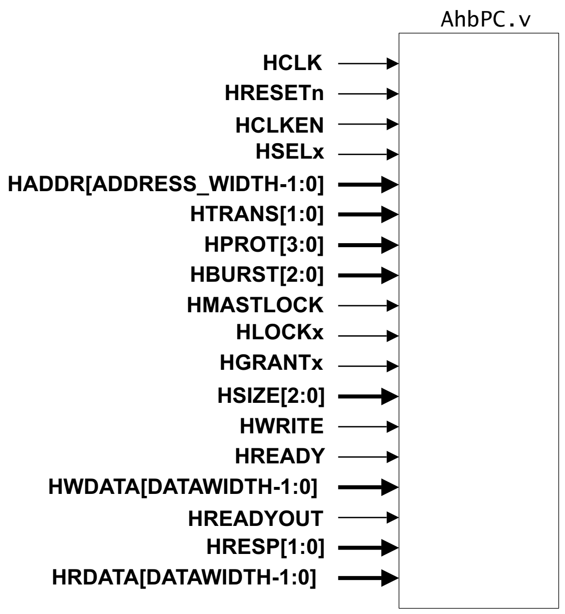


Figure 7-1 AHB protocol checker

When using the AHB protocol checker, signals such as **HGRANTx** and **HLOCKx** are not relevant to the Cortex-M processor, and therefore you can tie them LOW.

When an AHB bus protocol violation is detected, the transcript window of the simulator shows a warning message.

Table 7-1 shows the characteristics of the AHB protocol checker.

Table 7-1 AHB protocol checker characteristics

Element name	Description
Filename	`AhbPC.v`
Parameter	See Table 7-2 on page 7-3
Clock domain	**HCLK**

Table 7-2 shows the Verilog parameters and their descriptions.

Table 7-2 AHB Verilog parameters

Parameter	Description
`DATA_WIDTH`	Width of the data bus. The default value is 32 bits.
`ADDRESS_WIDTH`	Width of the address bus. The default value is 32 bits.
`ERRM_PropertyType`	Check for protocol errors in the bus master-generated signals: **0** Enable checking. This is the default. **1** Assume. Use this for formal verification. **2** Ignore.
`RECM_PropertyType`	Check for protocol recommendations in the bus master-generated signals: **0** Enable checking. This is the default. **1** Assume. Use this for formal verification. **2** Ignore.
`AUXM_PropertyType`	Check for auxiliary checks on the master-generated signals, for example, X state: **0** Enable checking. This is the default. **1** Assume. Use this for formal verification. **2** Ignore.
`ERRS_PropertyType`	Check for protocol errors in bus slave-generated signals: **0** Enable checking. This is the default. **1** Assume. Use this for formal verification. **2** Ignore.
`RECS_PropertyType`	Check for protocol recommendations in bus slave-generated signals: **0** Enable checking. This is the default. **1** Assume. Use this for formal verification. **2** Ignore.
`AUXS_PropertyType`	Check for auxiliary checks on slave-generated signals, for example, X state: **0** Enable checking. This is the default. **1** Assume. Use this for formal verification. **2** Ignore.

Table 7-3 shows the usage of the property type parameters.

Table 7-3 Use of property type parameters

Use	`ERRM_PropertyType`
	`RECM_PropertyType`
	`AUXM_PropertyType`
		`ERRS_PropertyType`
		`RECS_PropertyType`
		`AUXS_PropertyType`

In simulation	Set to 0 to check for issues in bus master-generated signals	Set to 0 to check for issues in the bus slave-generated signals
Formal verification, *Device Under Test* (DUT) is a bus master	Set to 0 to check for master-generated signals	Set to 1 to use assumptions to create constraints on the slave response
Formal verification, DUT is a bus slave	Set to 1 to use assumptions to create constraints on master-generated signals	Set to 0 to check for responses from the slave

Note

The AHB protocol checker is intended to be used to assist the detection of common AHB operation issues. It does not provide definitive checking of all bus protocol violation scenarios and do not provide all the constraints that formal verification requires.

7.2 AHB-Lite protocol checker

The AHB-Lite protocol checker, `AhbLitePC.v`, is a simulation model that you can use to detect bus protocol violations during simulation. The design is based on OVL. To use the AHB-Lite protocol checker, you must download the OVL Verilog library from Accellera, and add the OVL library path in the include and search paths of your simulator setup. Figure 7-2 shows the AHB-Lite protocol checker.

The example systems and a number of components already contain usage examples of the AHB-Lite protocol checker. The instantiation of AHB-Lite protocol checker is conditional in the examples, only when you set the `ARM_AHB_ASSERT_ON` compile directive. When using the AHB-Lite protocol checker in your design, you can use the compiler directive of your choice. Use of conditional compilation is required because the AHB-Lite protocol checker is not a synthesizable component.

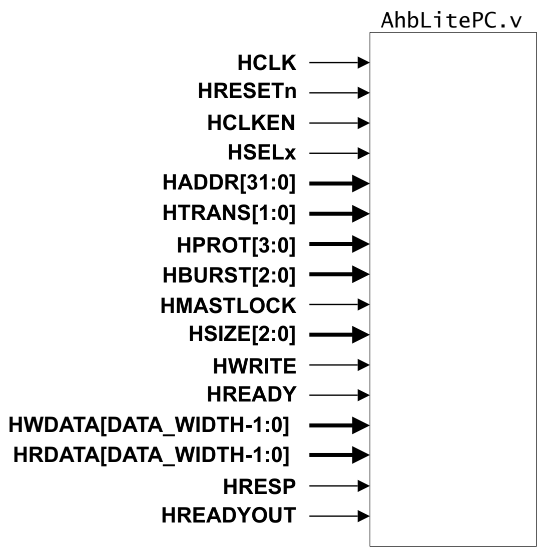


Figure 7-2 AHB-Lite protocol checker

This is a simplified version of the full AHB protocol checker, and no longer includes AHB2 signals such as **HMASTER**, **HGRANTx**, or **HLOCKx**. Furthermore, it supports only OKAY and ERROR type responses from the slave. The AHB-Lite protocol checker contains two main blocks of code that check the behavior of the design either from the slave, or from the master side.

When an AHB bus protocol violation is detected, warning messages are shown in the console or transcript window of the simulator.

Table 7-4 shows the characteristics of the AHB-Lite protocol checker.

Table 7-4 AHB-Lite protocol checker characteristics

Element name	Description
Filename	`AhbLitePC.v`
Parameter	See Table 7-5 on page 7-6
Clock domain	**HCLK**

Table 7-5 shows the Verilog parameters and their descriptions.

Table 7-5 AHB-Lite Verilog parameter descriptions

Parameter	Description
`DATA_WIDTH`	Width of the data bus. The default value is 32 bits.
`AHBLitePC_Master`	The AHB-Lite set of rules are generated according to this parameter: **0** Generate a separate set of rules for slave. **1** Generate a separate set of rules for master.
`AHBLitePC_Interconnect`	When used on the slave side, the AHB-Lite Protocol checker behaves differently when linked to an interconnect: **0** Check for the complete set of rules. This is the default. **1** Able to handle multi-layer interconnect termination.
`ERRM_PropertyType`	Check for protocol errors in the bus master-generated signals: **0** Enable checking. This is the default. **1** Assume, you use for formal verification. **2** Ignore.
`RECM_PropertyType`	Check for protocol recommendations in the bus master-generated signals: **0** Enable checking. This is the default. **1** Assume, you use for formal verification. **2** Ignore.
`AUXM_PropertyType`	Perform auxiliary checks on master-generated signals, for example, X state: **0** Enable checking. This is the default. **1** Assume. Use this for formal verification. **2** Ignore.
`ERRS_PropertyType`	Check for protocol errors in the bus slave-generated signals: **0** Enable checking. This is the default. **1** Assume. Use this for formal verification. **2** Ignore.
`RECS_PropertyType`	Check for protocol recommendations in the bus slave-generated signals: **0** Enable checking. This is the default. **1** Assume. Use this for formal verification. **2** Ignore.
`AUXS_PropertyType`	Perform auxiliary checks on slave-generated signals, for example, X state: **0** Enable checking. This is the default. **1** Assume. Use this for formal verification. **2** Ignore.

Table 7-6 shows the usage of the property type parameters.

Table 7-6 Use of property type parameters

Use	`ERRM_PropertyType` `RECM_PropertyType` `AUXM_PropertyType`	`ERRS_PropertyType` `RECS_PropertyType` `AUXS_PropertyType`	`AHBLitePC_Master`	`AHBLitePC_Interconnect`
In simulation	Set to 0 to check for issues in the bus master-generated signals.	Set to 0 to check for issues in bus slave-generated signals.	Set to 0 to check for issues when connected on the slave side. Set to 1 to check for issues when connected on the master side.	Set to 0 to check for issues on the slave side, when the general bus connection is used. Set to 1 to check for issues on the slave side, when a multi-layer component is used.
Formal verification, *Device Under Test* (DUT) is a bus master.	Set to 0 to check for master-generated signals.	Set to 1 to use assumptions to create constraints on slave response.	Set to 0 to generate a separate set of checks for the master signals.	Set to 0, when DUT is a general bus master. One, when DUT is a multi-layer interconnect.
Formal verification, DUT is a bus slave.	Set to 1 to use assumptions to create constraints on the master-generated signals.	Set to 0 to check for responses from slave.	Set to 1 to generate a separate set of checks for the slave signals.	When set to 0, the master are not permitted to terminate a burst request. signals.

Note

The AHB-Lite protocol checker is intended to be used to assist the detection of common AHB operation issues. It does not provide definitive checking of all bus protocol violation scenarios and do not provide all the constraints that formal verification requires.

7.3 APB protocol checker

The APB protocol checker is similar to the AHB protocol checker. See *AHB protocol checker* on page 7-2.

The APB protocol checkers, `ApbPC.v` and `Apb4PC.v`, are useful for detecting bus protocol issues in APB systems. The `ApbPC.v` supports APB3, and `Apb4PC.v` supports APB4.

To use the APB protocol checker, you must download the OVL Verilog library from Accellera, and add the OVL library path in the include and search paths of your simulator setup.

The example systems, and a number of components, already contain usage examples of the APB protocol checker in the AHB to APB bridge. The instantiation of the APB protocol checker is conditional in the examples, only when you set the `ARM_APB_ASSERT_ON` compile directive. When using the APB protocol checker in your design, you can use a compile directive of your choice. Use of conditional compilation is required because the APB protocol checker is not a synthesizable component.

Figure 7-3 shows the APB protocol checker for APB3.

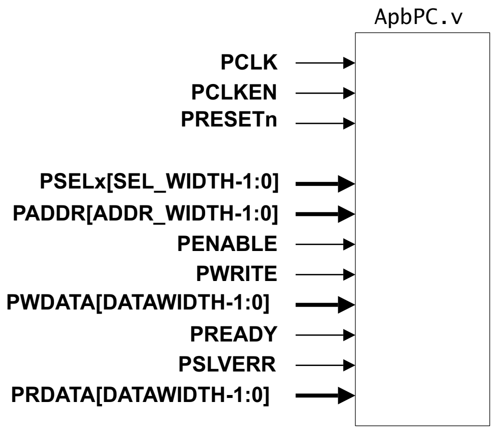


Figure 7-3 APB protocol checker for APB3

Figure 7-4 shows the APB protocol checker for APB4.

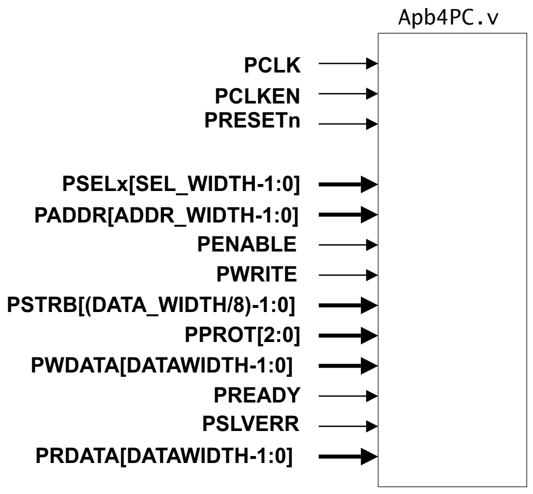


Figure 7-4 APB protocol checker for APB4

When an APB bus protocol violation is detected, the transcript window of the simulator shows a warning message.

Table 7-7 shows the characteristics of the APB protocol checker.

Table 7-7 APB protocol checker characteristics

Element name	Description
Filename	`ApbPC.v` and `Apb4PC.v`
Parameter	See Table 7-8
Clock domain	**PCLK**

Table 7-8 shows the Verilog parameters and their descriptions.

Table 7-8 APB Verilog parameter descriptions

Parameter	Description
`DATA_WIDTH`	Width of the data bus. The default value is 32 bits.
`ADDR_WIDTH`	Width of the address bus. The default value is 32 bits.
`SEL_WIDTH`	Width of **PSELx**. The default value is 32 bits.
`APB_ERRM_PropertyType`	Check for protocol errors in the bus master-generated signals: **0** Enable checking. This is the default. **1** Assume, you use for formal verification. **2** Ignore.
`APB_ ERRS_PropertyType`	Check for protocol errors in bus slave-generated signals: **0** Enable checking. This is the default. **1** Assume, you use for formal verification. **2** Ignore.
`APB_ERRP_PropertyType`	Perform checks on `ADDR_WIDTH` and `DATA_WIDTH` parameters: **0** Enable checking. This is the default. **1** Assume. Use this for formal verification. **2** Ignore.
`APB_PCLKEN_PropertyType`	Indicate if the optional **PCLKEN** signal is present: **0** Not present. **1** Present. This is the default.
`APB_PREADY_PropertyType`	Indicate if the optional **PREADY** signal is present: **0** Not present. **1** Present. This is the default.
`APB_PSLVERR_PropertyType`	Indicate if the optional **PSLVERR** signal is present: **0** Not present. **1** Present. This is the default.

Table 7-9 shows the usage of the property type parameters.

Table 7-9 Use of property type parameters

Use	`APB_ERRM_PropertyType`	`APB_ERRS_PropertyType`
In simulation	Set to 0 to check for issues in the bus master-generated signals	Set to 0 to check for issues in bus slave-generated signals
Formal verification, *Device Under Test* (DUT) is a bus master	Set to 0 to check for master-generated signals	Set to 1 to use assumptions to create constraints on slave response
Formal verification, DUT is a bus slave	Set to 1 to use assumptions to create constraints on the master-generated signals	Set to 0 to check for responses from slave

Note

The APB protocol checkers are intended to be used to assist the detection of common APB operation issues. They do not provide definitive checking of all bus protocol violation scenarios and do not provide all the constraints that formal verification requires.

7.4 AHB FRBM

The AHB FRBM, `ahb_fileread_master32.v` and `ahb_fileread_master64.v`, enable designers to simulate AHB systems quickly and efficiently by using them to generate explicit bus transfers. The FRBM can operate in the Cortex-M System Design Kit with or without an ARM core present. The FRBM and its perl script are compatible with the version in the FRBM in ADK.

The FRBM is a generic AHB *Bus Functional Model* (BFM) that directly controls bus activity by interpreting a stimulus file. The FRBM facilitates the efficient validation of blocks or systems.

The 64 bits FRBM, `ahb_fileread_master64.v`, is split into the following parts:

- AHB-Lite file reader
- AHB-Lite to AHB wrapper.

The 32 bits FRBM, `ahb_fileread_master32.v`, has an additional part, the funnel, that converts 32 bits transfers on a 64 bits bus to 32 bits transfers on a 32 bits bus.

The AHB-Lite file reader can:

- perform all AHB burst types at data widths of 8, 16, 32, and 64 bits
- insert BUSY states during bursts
- perform idle transfers
- compare received data with the expected data and report the differences during simulations.

The stimulus file controls the AHB-Lite file reader at simulation run time. It does not have a slave interface, and therefore other AHB masters cannot address it.

You must transform the human-readable input stimulus file to a data file in Verilog hexadecimal format using the `fm2conv.pl` preprocessor script.

The FRBM is designed so that, wherever possible, RTL code is used to describe its logic. All RTL code is written for synthesis using pragmas where necessary, to enable the block to pass through synthesis tools.

Figure 7-5 shows a block diagram of the 32 bits AHB FRBM.

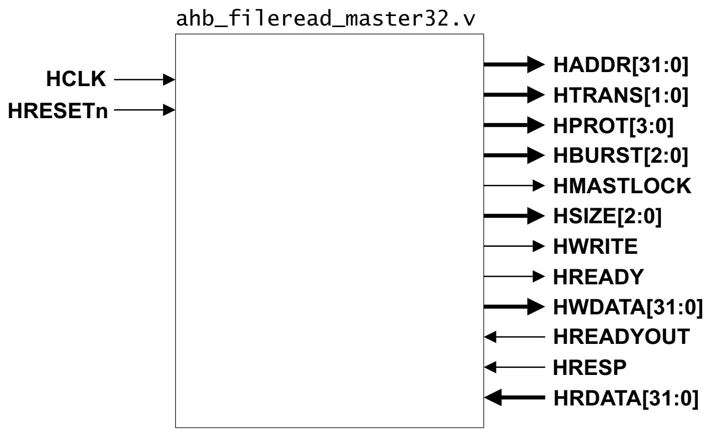


Figure 7-5 32 bits AHB FRBM

Figure 7-6 on page 7-12 shows a block diagram of the 64 bits AHB FRBM.

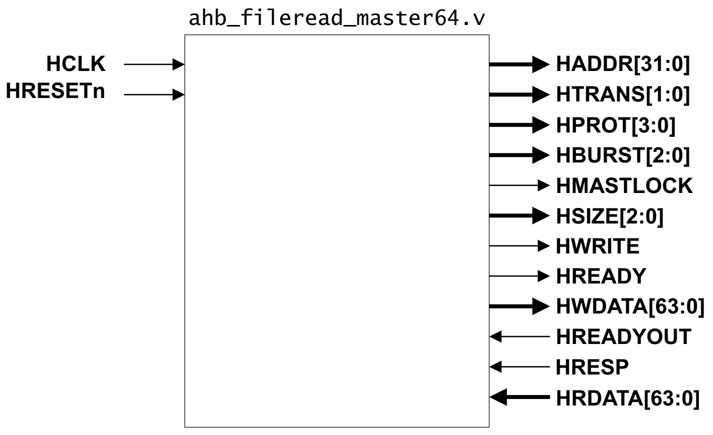


Figure 7-6 64 bits AHB FRBM

Table 7-10 shows the characteristics of the FRBM.

Table 7-10 FRBM characteristics

Element	Description
Filenames	`ahb_fileread_master32.v` and `ahb_fileread_master64.v`
Parameters	The parameters are as follows: `InputFileName` Stimulus file. The default value is `filestim.m2d`. `MessageTag` Tag on each FileReader message. The default value is `FileReader`. `StimArraySize` Stimulus data array size. The default value is 5000.
Clock domain	**HCLK**

7.4.1 Programmers model

The `ahb_fileread_master` uses the following Verilog parameters:

`InputFileName`	This is the name of the stimulus data file to be read. If the file is not found, simulation is aborted. The default file name is `filestim.m2d`.
`MessageTag`	A string that is prepended to all stimulation messages from this `ahb_fileread_master`. You can use this tag to differentiate between messages from multiple FRBMs in a system. The default message tag is `FileReader`.
`StimArraySize`	The size, in words, of the internal array used to store the stimulus data. This value has a direct effect on the simulation startup time and memory requirement. This value is large enough to store the whole data file. If the data file is larger than the array, simulation is aborted. The default value is 5000.

The following sections describe the AHB-Lite FRBM functions:

- *Write command* on page 7-13
- *Read command* on page 7-13
- *Sequential command* on page 7-14
- *Busy command* on page 7-15
- *Idle command* on page 7-16
- *Poll command* on page 7-17

- *Loop command* on page 7-18
- *Resp field* on page 7-18
- *Clock and reset* on page 7-18
- *Error reporting at runtime* on page 7-19
- *End of stimulus* on page 7-19.

Write command

The `write` command, `W`, starts a write burst and one or more S vectors can follow it. For bursts of fixed length, the Burst field determines the number of S vectors. For bursts of undefined length, there can be any number of S vectors as long as they do not cause the address to cross a 1KB boundary.

Figure 7-7 shows the `write` command timing diagram.

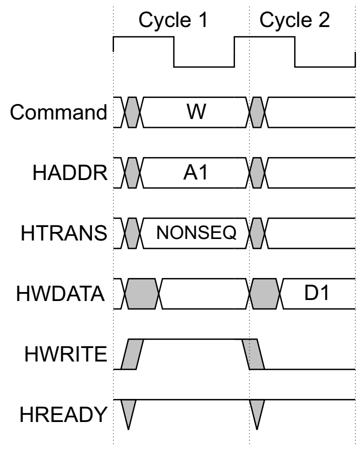


Figure 7-7 Write command timing

The `write` command operates as follows:

Cycle 1 The file reader sets up the control signals from the command and asserts **HWRITE**. **HTRANS** is NONSEQ to indicate the first transfer of the burst. The Data field is stored and ready to be driven during the data phase.

If **HREADY** is asserted, the file reader proceeds to the second control phase.

Cycle 2 This is the first data phase in which the data is driven for the previous cycle. Unless the Burst field specifies a single transfer, the file reader calculates the next address based on the Size and Burst values.

Read command

The `read` command, `R`, starts a read burst and one or more S vectors can follow it. For bursts of fixed length, the Burst field determines the number of S vectors. For bursts of undefined length, there can be any number of S vectors as long as they do not cause the address to cross a 1KB boundary.

Figure 7-8 on page 7-14 shows the `read` command timing diagram.

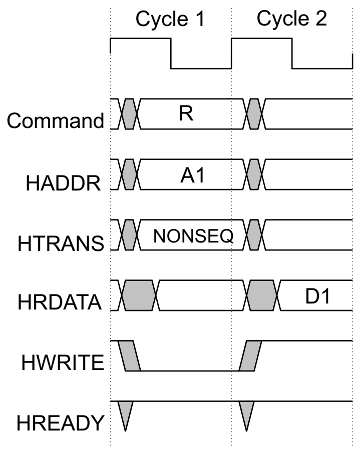


Figure 7-8 Read command timing

The `read` command operates as follows:

Cycle 1 The file reader sets up the control signals from the command and deasserts **HWRITE**. **HTRANS** is NONSEQ to indicate the first transfer of a burst.

If **HREADY** is asserted, the file reader proceeds to the second control phase.

Cycle 2 The data read for the previous cycle is compared with the Data field after applying the mask and byte lane strobes. Any differences are reported to the simulation environment. Unless the Burst field indicates a single transfer, the file reader calculates the next address based on the Size and Burst values.

Sequential command

The `sequential` command, `S`, is a vector that provides data for a single beat within the burst. The file reader calculates the required address. A `sequential` command is valid when a `read` or `write` command starts a burst transfer.

Figure 7-9 shows the `sequential` command timing diagram.

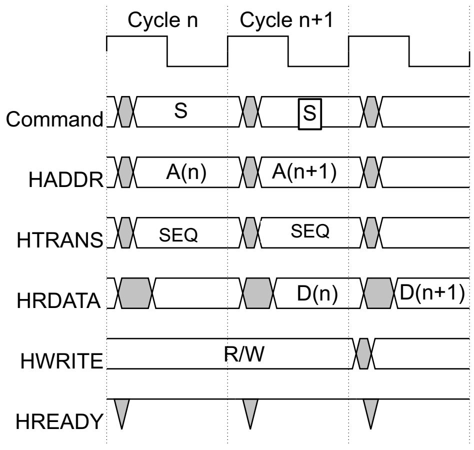


Figure 7-9 Sequential command timing

A `sequential` command is valid when a `read` or `write` command starts a burst transfer and operates as follows:

Cycle n The file reader drives the calculated address, and **HTRANS** is SEQ to indicate the remaining transfers of the burst.

If **HREADY** is asserted, the file reader proceeds to the second control phase.

Cycle n + 1 In a write burst, the file reader drives the Data field data and ignores the Mask field.

In a read burst, the file reader applies the Mask and Bstrb fields to the input data and then compares the Data field with the input data. The file reader reports differences between the expected data and the read data to the simulation environment.

Busy command

The `busy` command, `B`, inserts either a BUSY transfer or a BUSY cycle, depending on the Wait field. A `busy` command is valid when a `read` or `write` command starts a burst transfer.

During a burst with the Wait field not specified, the `busy` command inserts a single **HCLK** BUSY transfer on the AHB. A burst can have a `busy` command after its last transfer while the master determines whether it has another transfer to complete.

Figure 7-10 shows the busy command timing diagram.

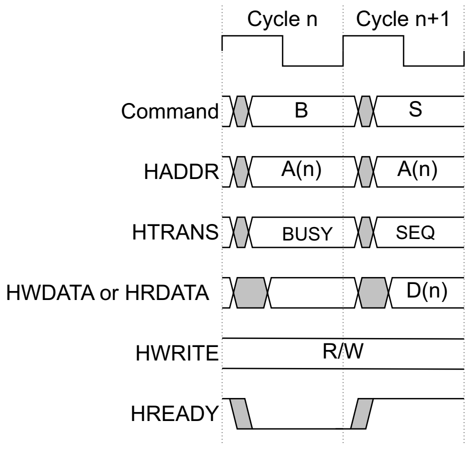


Figure 7-10 Busy transfer timing

Cycle n The file reader drives the calculated address and **HTRANS** is BUSY.

Cycle n + 1 The file reader proceeds to the next control phase. Data is ignored.

During a burst with the Wait field specified, the `busy` command inserts a complete AHB transfer. See Figure 7-11 on page 7-16.

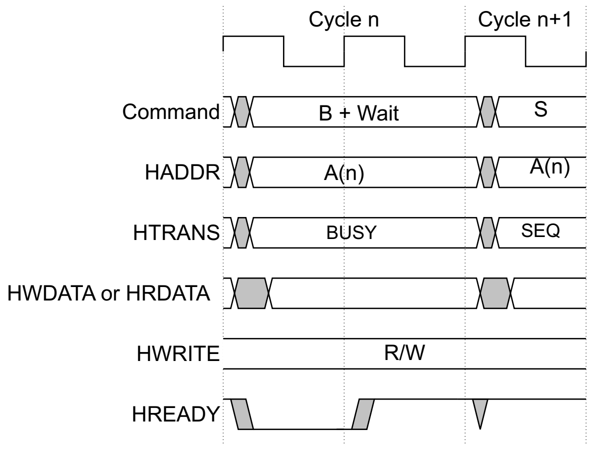


Figure 7-11 Busy cycle timing

The address phase is extended by wait states because of the data phase of a previous transfer, if present.

Idle command

The `idle` command, `I`, performs either an IDLE transfer or an IDLE cycle, depending on the Wait field. The options enable you to set up the control information during the IDLE transfer, and to specify whether the transfer is locked or unlocked.

If the Wait field is not specified, the `idle` command inserts a single **HCLK** cycle IDLE transfer on the AHB. See Figure 7-12.

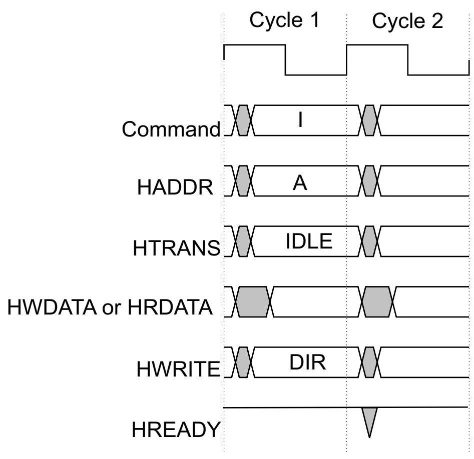


Figure 7-12 Idle transfer timing

Cycle 1 **HTRANS** is IDLE and the control signals take the default values, except for those specified in the command.

Cycle 2 The file reader proceeds to the next control phase. Data is ignored.

If the Wait field is specified, the `idle` command inserts a complete AHB transfer. See Figure 7-13 on page 7-17. The address phase is extended by wait states because of the data phase of a previous transfer, if present.

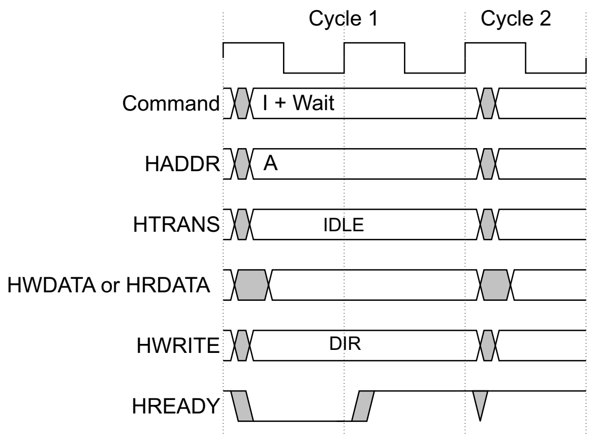


Figure 7-13 Idle cycle timing

Cycle 1 **HTRANS** is set to IDLE and the control signals are set to the default values, except for those specified in the command.

Cycle 2 If the Wait field is not specified, or the Wait field is specified and **HREADY** is asserted, then the file reader proceeds to the next control phase. Data is ignored.

Poll command

The `poll` command, `P`, continually reads the input data until it matches the value in the Data field or until the number of reads equals the number in the Timeout field. If the input data does not match after the Timeout number, the file reader reports an error. Not specifying a Timeout value or specifying a Timeout value of 0, causes the `poll` command to read continually until the data matches the required value. The `poll` command is valid only for INCR or SINGLE burst types and for aligned addresses.

Figure 7-14 shows the `poll` command timing diagram.

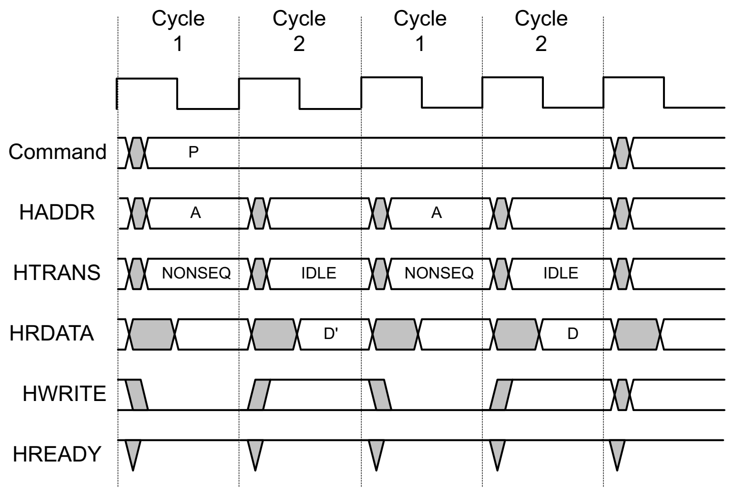


Figure 7-14 Poll command timing

The poll command operates as follows:

Cycle 1 The file reader sets up a read of the single address in the Address field.

If **HREADY** is asserted, the file reader proceeds to the second control phase.

Cycle 2 The file reader issues an IDLE transfer and reads the data for the previous address value.

Loop command

The `loop` command, `L`, repeats the last command a number of times. When the burst type is INCR or SINGLE, a `loop` command must follow only a `write` or `read`. Because the file reader has a 32 bits counter, the maximum number of loops is 2^{32} -1.

——— **Note** ———

Commands that do not directly represent bus transactions, for example, the simulation comment command `C`, are not looped. Consecutive loops are cumulative and not multiplicative. For example:

```
I 0x4000
C Commencing IDLES
L 1000
L 1000
```

This sequence performs an `idle` command to address `0x4000`, generates the comment, and then performs 2000 more IDLE accesses to address `0x4000`.

———————————

Comment command

The `comment` command, `C`, sends a message to the simulation window.

Quit command

The `quit` command, `Q`, causes the simulation to terminate immediately. Additionally, the `quit` command provides a summary of the number of commands and errors.

Resp field

The `Resp` field tests for the expected response. You must present the `Resp` field on a command that is expected to receive an ERROR response from a slave.

If the `Resp` field is set to `Errorcont` or `Errorcanc`, and an ERROR response is received, no warning is issued. If the `Resp` field is set to `Errorcont` or `Errorcanc`, and an ERROR response is not received, a simulation warning is generated.

If an error occurs during a burst transfer, and the `Resp` field is set to `Errorcont`, the burst continues.

If an error occurs during a burst transfer and the `Resp` field is set to `Errorcanc`, the burst is cancelled. No attempt is made to retransmit the erroneous transfer. It is not necessary for the stimulus file to contain the remaining transfers in the burst. An IDLE transfer is always inserted during the ultimate cycle of the ERROR response if the burst is to be cancelled.

Clock and reset

The file reader is synchronous to the AHB bus clock signal **HCLK** and the AHB reset signal **HRESETn** resets it.

Error reporting at runtime

An error can occur in the following circumstances:

- a read transfer where the expected data does not match the actual data
- a transfer that receives an AHB ERROR response and the Error field is not set
- a transfer where the Error field is set and the transfer does not receive an AHB ERROR response
- a `Poll` command where the expected data is not received within the timeout number of attempts
- the stimulus file is longer than the array size allocated.

When an error is reported, the line number of the corresponding command on the input file is reported to the simulation window.

End of stimulus

A summary of the number of commands and errors is given when any of the following is reached:

- a quit command
- end of input file
- end of the internal command array.

Simulation is terminated when a `Q` command is encountered.

When the stimulus ends, all AHB signals are set LOW. This implies IDLE read transfers to address `0x00`.

If the end of the internal command array is reached, and the end of the stimulus file has not been reached, a warning is issued, and all AHB signals are set LOW. This implies IDLE read transfers to address `0x00`.

7.4.2 Command syntax

The filename of the stimulus data file is specified using a Verilog parameter, at the point of instantiation in the HDL code.

The syntax uses a single letter for each command followed by a number of fields.

Command syntax

Table 7-11 shows the stimulus command syntax.

Table 7-11 Stimulus command syntax

Cmd	Fields								
`W`	Address	Data		[Size]	[Burst]	[Prot]	[Lock]	[Resp]	[Comment]
`R`	Address	Data	[Mask]	[Size]	[Burst]	[Prot]	[Lock]	[Resp]	[Comment]
`S`	-	Data	[Mask]	-	-	-	-	[Resp]	[Comment]
`B`	-	-	-	-	-	-	-	[Wait]	[Comment]
`I`	[Address]	[Dir]	-	[Size]	[Burst]	[Prot]	[Lock]	[Wait]	[Comment]
`P`	Address	Data	[Mask]	[Size]	[Burst]	[Prot]	[Timeout]	-	[Comment]

Table 7-11 Stimulus command syntax (continued)

Cmd	Fields								
`L`	Number	-	-	-	-	-	-	-	[Comment]
`C`	Message	-	-	-	-	-	-	-	[Comment]
`Q`	-	-	-	-	-	-	-	-	[Comment]

Note

Items in square brackets [] are optional. See Table 7-12 on page 7-21 for default values.

The commands are:

`W`	The `write` command starts a write burst and one or more S vectors can follow it. The number of S vectors is set by the size and burst fields for fixed length bursts. There is no limit to the number of S vectors for undefined length bursts, as long as it does not cause the address to cross a 1KB boundary.
`R`	The `read` command starts a read burst and one or more S vectors can follow it. The number of S vectors is set by the size and burst fields for fixed length bursts. There is no limit to the number of S vectors for undefined length bursts, as long as it does not cause the address to cross a 1KB boundary.
`S`	The sequential vector provides data for a single beat in the burst. The file reader calculates the address required.
`B`	The `busy` command inserts either a BUSY cycle or a BUSY transfer mid burst, depending on the value of the Wait field. An INCR burst can have a busy after its last transfer, while the master determines whether it has another transfer to complete. It is not valid to have a busy command when a burst is not in progress.
`I`	The `idle` command performs either an IDLE cycle or an IDLE transfer, depending on the value of the Wait field. The options enables you to set up the control information during the idle transfer, and to specify whether the transfer is locked or unlocked.
`P`	The `poll` command performs a read transfer that repeats until the data matches the required value. If it repeats this Number times, and the value is not read, then an error is reported. Either omitting Timeout or setting it to 0 causes the Poll to repeat continually until the data matches the required value. You can use the poll vector for INCR or SINGLE burst types and for aligned addresses.
`L`	The `loop` command repeats the last command a number of times. An `L` command must only follow a `W` or `R` when the burst type is INCR or SINGLE.
`C`	The `comment` command, `C`, sends a message to the simulation window.
`Q`	The `quit` command, `Q`, causes the simulation to terminate immediately. Additionally, the quit command gives a summary of the number of commands and errors.

Table 7-12 shows the stimulus command fields.

Table 7-12 Command fields

Field	Default	Values	Prefix	Description
Address	`0x00000000`	32 bits hex value	`0x`, optional	First address of burst.
Data	-	8, 16, 32, or 64 bits hex value	`0x`, optional	Data field for `read`, `write`, `sequential`, and `poll` commands. The width of the Data field must match either the specified transfer size or the bus width of the FRBM.
Mask	`0xFF` for each active byte lane as determined by Address and Size, and `0x00` for inactive byte lanes, or `0xFFFFFFFF` if `adk1` switch is set	8, 16, 32, or 64 bits hex value	`0x`, optional	Bit mask. Enables masking of read data when testing against required data. You must write the Mask and Data fields as the same size. They must match either the specified transfer size or the bus width of the FRBM.
Size	`word` or `doubleword` depending on user-defined `-buswidth` switch	`b | byte | size8 | h | hword | size16 | w | word | size32 | d | dword | size64`	-	Data size for `read`, `write`, `sequential`, and `poll` commands.
Burst	`incr`	`sing | single | incr | incr4 | wrap4 | incr8 | wrap8 | incr16 | wrap16`	-	Burst type for `read`, `write`, and `idle` transfer commands. For the `poll` command, the only permitted values for Burst are `sing`, `single`, or `incr`.
Prot	`0000`	4 bits binary	`p | P`	Indicates the **HPROT** value for the transfer.
Lock	`nolock`	`nolock | lock`	-	Transfers lock.
Resp	`okay`	`okay | ok | errcanc | errcanc`	-	When `errcont` is specified:[a] • If an ERROR response occurs, no warning is generated. A burst in progress continues. • If no ERROR response occurs, a warning is generated. A burst in progress continues. When `errcanc` is specified: • If an ERROR response occurs, no warning is generated. A burst in progress is cancelled.[b] • If no ERROR response occurs, a warning is generated. A burst in progress continues.
Dir	`read`	`read | write`	-	Controls the value of **HWRITE** during an `idle` command.
Number	-	Decimal value from 1-(2^{32}-1)	-	Loops repeat value.

Table 7-12 Command fields (continued)

Field	Default	Values	Prefix	Description
Timeout	`0`	Decimal value from 0-(2^{32}-1)	`t` | `T`	Number of times the `poll` command repeats the data check before generating an error when data does not match the expected value. Specifying 0 repeats continuously.
Wait	`nowait`	`wait` | `nowait`	-	Waits for **HREADY** before continuing. Makes an IDLE or BUSY cycle.
Message	-	1 to 80 characters and symbols. See Table 7-13 for supported characters.	Comment contained within double quotes	Sends a user-defined comment to the simulation window.
Comment Delimiter	-	; | # | // | --	-	All common comment delimiters are valid.

a. You can use the value `err` or `error` as a synonym for `errcont` for compatibility with legacy BFM versions, but it is not recommended for use in new development.

b. An IDLE transfer is always inserted in the last cycle of the ERROR response if the burst is cancelled. No attempt is made to retransmit the erroneous transfer. It is not necessary for the stimulus file to contain the remaining transfers of the burst.

Table 7-13 shows the keyboard characters that are supported by the `comment` command. For other characters replace with a dash, -, character by the script.

Table 7-13 Characters supported by `comment` command

Character	Symbol							
a-z, lower case	!	$	%	^	&	*	(	)
A-Z, upper case	_	-	+	=	{	}	[	]
0-9	:	;	@		'~	#	<	>
White space	,	.	?	/	|			

7.4.3 File preprocessing

The stimulus file is converted into a format that can feed directly into the HDL code using the `fm2conv.pl` script. This script verifies that the syntax of the input file is correct. This script provides useful error messages when the syntax is incorrect. Figure 7-15 shows the process of stimulus file conversion.

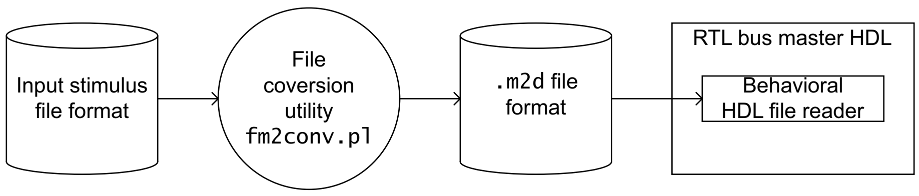

Input stimulus file format
File coversion utility fm2conv.pl
.m2d file format
RTL bus master HDL
Behavioral HDL file reader

Figure 7-15 Stimulus file conversion

Loops

The `fm2conv.pl` script unfolds loops of S vectors, but relies on the FRBM functionality for other commands.

Note

Large loops of S vectors can create large stimulus data files.

Data and mask representations

You can specify data and mask values as any of the following:

- the bus width
- with the `-buswidth` switch to `fm2conv.pl`
- the same length as the transfer size with or without a `0x` prefix.

The byte lanes are driven according to both the least significant address bits, and the specified endian organization. The default is little-endian.

If the data or mask are represented as fewer bits than the data bus, then the transfer size is implicitly set to be that width. If this value conflicts with an explicit Size field, then an error is generated. The following examples show data and mask representations of fewer bits than the data bus:

`R 00000002 DD`

Read transfer with burst type INCR and implied size BYTE. The Data mask is `0x0000000000FF0000` in default little-endian mode.

`R 0000ABCD 0x0123456789ABCDEF AB`

The data field is 64 bits, that is, the bus width, and the mask field is BYTE, so the transfer size is BYTE.

`R 00000004 EEEEEEEE FF`

Invalid stimulus on a 64 bits system. The data field implies a word transfer whereas the mask field implies BYTE.

`W 000000C0 AB WORD`

Invalid stimulus. The Data field implies a byte transfer whereas the Size field specifies word transfer.

FRBM versions

Because the FRBM and `fm2conv.pl` utilities are closely coupled through the stimulus data file, you must take care to ensure that you use the correct versions. Table 7-14 shows the compatibility between versions.

Table 7-14 Compatibility between versions of FRBM and `fm2conv.pl`

`fm2conv.pl` **version**	
ADK 1.0	**ADK 2.0**
File reader version ADK 1.0	-
-	File reader version ADK 2.0

Because of enhancements in FRBM functionality and stimulus extensions, the stimulus files and data files for the AHB file reader are incompatible with previous versions of the file reader. The file preprocessor can translate ADK 1.0 stimulus files using the corresponding command-line switch. You can identify the versions by their ADK version keyword as follows:

ADK_REL1v	For previous versions.
ADK2v	For the FRBM that this document describes.

Table 7-15 shows the compatibility between versions.

Table 7-15 Compatibility between versions of stimulus file and `fm2conv.pl`

`fm2conv.pl` **version**	
ADK 1.0	ADK 2.0
Stimulus file version ADK 1.0	Stimulus file version ADK 1.0[a]
-	Stimulus file version ADK 2.0

a. Using `-adk 1.0` command-line switch.

Endianness

By default, the preprocessor script assumes little-endian data organization. Therefore, if only a single byte of data is specified for a byte access, it is placed on the byte lane that the little-endian addressing determines.

Big-endian mode is supported for AMBA 2.0. The type of big-endian is legacy big-endian, also called ARM big-endian or BE-32. You must specify the data and mask in the same way as for little-endian mode. The preprocessor script places the data and mask bytes in the correct lanes.

Stimulus file size

When the file reader simulation begins, the entire stimulus file is read into an array. Ensure that the array size is large enough to store the entire stimulus file. The `fm2conv.pl` utility reports the array size required and the total number of vectors in a summary of the stimulus file conversion. A warning is generated if the array size is too small for the resulting stimulus file.

If the array size in the RTL file reader bus master is changed from the default value, you can set the array size using a generic parameter in the FRBM HDL by using the `-stimarraysize` command line switch with the `fm2conv.pl` utility.

File preprocessor usage

Table 7-16 shows the command-line switches that the `fm2conv.pl` preprocessor accepts.

Table 7-16 Preprocessor command-line options

Switch	Options	Default	Description
`-help`	-	-	Displays the usage messages.
`-quiet`	-	-	Suppresses warning messages.
`-adk1`	-	-	Translates an ADK 1.0 stimulus file. You can also specify this option within the stimulus file.

Table 7-16 Preprocessor command-line options (continued)

Switch	Options	Default	Description
`-endian = <endianness>`	`little` or `big`	`little`	The endianness determines the byte lanes that are driven for sparsely declared Data and Mask fields. This is not supported for v6 stimulus. Instead, you must specify the full bus width for big-endian transfers. The big-endian option is implemented as ARM big-endian.
`-infile = <filename>`	-	`filestim.m2i`	Input file name.
`-outfile = <filename>`	-	`filestim.m2d`	Output file name. This name must match the definition specified in the file reader bus master HDL.
`-buswidth = <width>`	`32` or `64`	`64`	Specifies the data bus width of the target FRBM.
`-arch = <arch>`	`ahb2` or `V6`	`ahb2`	Specifies the ARM processor architecture version of the target FRBM. **Note** This version of the FRBM does not support V6.
`-StimArraySize = <size>`	`<size>`	`5000`	The size of the file reader bus master file array. This size must match the value set in the FRBM HDL.

Error reporting during file preprocessing

The script performs additional checks to ensure correct FRBM operation. Table 7-17 shows the error checks. File conversion is aborted if an error with the command-line options is found. File conversion continues if any other error is found, so that you can generate non-AMBA compliant stimulus for test purposes, if required.

Table 7-17 `fm2conv.pl` error messages

Error number	Description
17	Input file is unreadable, does not exist or has incorrect permissions.
20	Input file has the same name as the output file.
21	Cannot create the output file.
32	Unrecognized commands within the file.
36	Required fields are missing or in the wrong format.
37	Loop command has the `Number` field missing.
38	`Comment` command requires a string within double quotes.
40	`Size` value exceeds the data bus width. The maximum value is `dword | size64` for the ADK 2.0 64 bits version FRBM, and `word | size32` for the ADK 2.0 32 bits version FRBM.
43	Loop `Number` field is out of range.
44	Poll `TimeOut` field is out of range.
48	`Data` field length exceeds the FRBM data bus width.
49	`Data` field has an invalid length.
52	`Mask` field length exceeds the FRBM data bus width.

Table 7-17 `fm2conv.pl` error messages (continued)

Error number	Description
53	`Mask` field has an invalid length.
56	Mismatch between transfer size, whether specified or implicitly set by the Data or the Mask width, and the Data or Mask field.
64	Address is not aligned with the size of the transfer.
80	For Poll commands, burst types are not the valid INCR or SINGLE.
84	S or B vectors before a defined-length or undefined-length burst has started.
88	Burst exceeds the 1KB address boundary, for both defined and undefined-length bursts.
89	Loop number exceeds the number of remaining transfers, for each defined-length burst type.

The most common AMBA protocol violations are detected by the file preprocessor script, but the absence of errors and warnings does not guarantee that the stimulus are compliant with the AMBA protocol.

Table 7-18 shows the warnings. File conversion continues when a warning is issued.

Table 7-18 `fm2conv.pl` warnings

Warning number	Description
128	Perl version is older than 5.005. Command line switches are not supported.
132	Invalid data bus width is selected.
133	Invalid architecture is selected.
134	ADK 1.0 architecture is selected and the data bus width is not specified as 32 bits.
136	Output file length exceeds the specified size of the stimarraysize.
144	EOF found during a burst, and additional transfers are expected.
164	An optional field has an invalid value.
165	Invalid character exists in the comment string.
168	Comment command has a string of length greater than 80 characters.
169	Consecutive blank or commented lines exceed 63 for the line number reporting to work.
216	Number of S vectors following a `W | R` command is incorrect for a fixed length burst, and a burst is terminated early. This enables the simulation of early-terminated bursts.
240	Unsupported memory command is encountered.
241	Unsupported AltMaster field is encountered and the entire line is ignored.
242	Unsupported DeGrant field is encountered and is ignored.
248	A feature in development status.
254	Currently unsupported value in a field, for example, size > 64.
255	Internal or debug error. Not expected to occur in normal usage.

Errors and warnings have the following numbering scheme:

[7]	Severity.
[6:4]	Error or warning type.
[3:2]	Error or warning subtype.
[1:0]	Enumerator.

Table 7-19 shows the numbering scheme for bit 7, severity.

Table 7-19 Numbering scheme for bit 7, severity

Value	Meaning
0	Error
1	Warning

Table 7-20 shows the numbering scheme for bits [6:4] and [3:2], error and warning type and subtype.

Table 7-20 Numbering scheme for bits [6:4] and [3:2], error and warning type and subtype

Value bits [6:4]	Meaning	Value bits [3:2]	Meaning
`000`	Command line	00	Environment
		01	Options
		10	-
		11	-
`001`	File input or output	00	Input file
		01	Output file
		10	-
		11	-
`010`	Syntax	00	Command
		01	Field
		10	Range
		11	-
`011`	Transfer size	00	Data
		01	Mask
		10	Mismatch
		11	-
`100`	Alignment	00	Address
		01	-
		10	-
		11	-

Table 7-20 Numbering scheme for bits [6:4] and [3:2], error and warning type and subtype

Value bits [6:4]	Meaning	Value bits [3:2]	Meaning
`101`	Burst	00	Within burst
		01	Outside burst
		10	Length
		11	-
`110`	Reserved	-	-
`111`	Reserved	-	-

Table 7-21 shows the numbering scheme for bits [1:0], enumerator.

Table 7-21 Numbering scheme for bits [1:0], enumerator

Value	Meaning
(any)	Creates a unique identifier in conjunction with bits [7:2]

Appendix A **Revisions**

This appendix describes the technical changes between released issues of this book.

Table A-1 Differences between issue B and issue A

Change	Location	Affects
Added the following section in *AHB upsizer* on page 5-14: • *Method of using AHB upsizer* on page 5-14	Chapter 5 *Advanced AHB Components*	r0p0
Added the following section in *AHB downsizer* on page 5-17: • *Using AHB downsizer* on page 5-23	Chapter 5 *Advanced AHB Components*	r0p0
Added the following section in *AHB to APB asynchronous bridge* on page 5-26: • *Cross-clock domain handling in AHB to APB asynchronous bridge* on page 5-27	Chapter 5 *Advanced AHB Components*	r0p0
Added the following section in *AHB to AHB synchronous bridge* on page 5-28: • *Using AHB to AHB synchronous bridge* on page 5-29	Chapter 5 *Advanced AHB Components*	r0p0
Added the following section in *AHB to AHB sync-down bridge* on page 5-30: • *Using the AHB to AHB sync-down bridge* on page 5-31 • *Optional write buffer* on page 5-32 • *Synthesizing the AHB to AHB sync-down bridge* on page 5-33.	Chapter 5 *Advanced AHB Components*	r0p0
Added the following section in *AHB to AHB sync-up bridge* on page 5-35: • *Using the AHB to AHB sync-up bridge* on page 5-36 • *Synthesizing the AHB to AHB sync-up bridge* on page 5-37.	Chapter 5 *Advanced AHB Components*	r0p0