NS9775 Hardware Reference

Making DEVICE NETWORKING easy™

90000524_E

NS9775 Hardware Reference

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Using This Guide

Review this section for basic information about the guide you are using, as well as general support and contact information.

About this guide

This guide provides information about the Digi NS9775, a single chip 0.13µm CMOS network-attached processor. The NS9775 is part of the Digi NET+ARM family of devices.

The NET+ARM family is part of the NET+Works integrated product family, which includes the NET+OS network software suite.

Who should read this guide

This guide is for hardware developers, system software developers, and applications programmers who want to use the NS9775 for development.

To complete the tasks described in this guide, you must:

- Understand the basics of hardware and software design, operating systems, and microprocessor design.
- Understand the NS9775 architecture.

What's in this guide

This table shows where you can find specific information in this guide.

To read about	See
NS9775 key features	Chapter 1, "About the NS9775
NS9775 ball grid array assignments	Chapter 2, "NS9775 Pinout"
NS9775 CPU	Chapter 3, "Working with the CPU"
System functionality	Chapter 4, "System Control Module"
How the NS9775 works with the Multiport Memory Controller, an AMBA-compliant SoC peripheral	Chapter 5, "Memory Controller"
How the NS9775 works with Ethernet MAC and Ethernet front-end module	Chapter 6, "Ethernet Communication Module"
PCI-to-AHB bus functionality, which connects PCI-based devices to the NS9775 AHB bus	Chapter 7, "PCI-to-AHB Bridge"
Digi proprietary BBus	Chapter 8, "BBus Bridge
NS9775 BBus DMA controller subsystem	Chapter 9, "BBus DMA Controller"
Chip-level support for low-speed peripherals	Chapter 10, "BBus Utility"
Interface between the ARM CPU and the I^2C bus	Chapter 11, "I^2C Master/Slave Interface"
LCD controller	Chapter 12, "LCD Controller"
UART mode serial controller	Chapter 13, "Serial Control Module: UART"
SPI mode serial controller	Chapter 14, "Serial Control Module: SPI"
IEEE 1284 peripheral port	Chapter 15, "IEEE 1284 Peripheral Controller"
USB 2.0	Chapter 16, "USB Controller Module"
NS9775 electrical characteristics and timing diagrams and information	Chapter 17, "Timing"
NS9775 packaging information	Chapter 18, "Packaging"

Conventions used in this guide

This table describes the typographic conventions used in this guide:

This convention	Is used for
italic type	Emphasis, new terms, variables, and document titles.
`monospaced type`	Filenames, pathnames, and code examples.
_ (underscore)	Defines a signal as being active low.
'b	Indicates that the number following this indicator is in binary radix
'd	Indicates that the number following this indicator is in decimal radix
'h	Indicates that the number following this indicator is in hexadecimal radix
RW1TC	Indicates Read/Write 1 to clear.

Related documentation

- *NS9775 Jumpers and Components* provides a hardware description of the NS9775 development board, and includes information about jumpers, components, switches, and configuration.
- *NS9775 Sample Driver Configurations* provides sample configurations that you can use to develop your drivers.

Review the documentation CD-ROM that came with your development kit for information on third-party products and other components.

See the NET+OS software documentation for information appropriate to the chip you are using.

Documentation updates

Digi occasionally provides documentation updates on the Web site.

Be aware that if you see differences between the documentation you received in your package and the documentation on the Web site, the Web site content is the latest version.

Customer support

To get help with a question or technical problem with this product, or to make comments and recommendations about our products or documentation, use the contact information listed in this table:

For	Contact information
Technical support	United States: +1 877 912-3444 Other locations: +1 952 912-3444 www.digi.com/support www.digi.com

About NS9775

CHAPTER 1

The Digi NS9775 is a high-performance, 32-bit microprocessor for color network printers and multi-function devices. This chapter provides an overview of the NS9775, which is based on the standard architecture in the NET+ARM family of devices.

NS9775 Features

The NS9775 integrates an ARM926EJ-S processor core with 10/100BaseT Ethernet, USB, IEEE 1284 interfaces, a 4-channel video interface with four inline JBIG decompressors, LCD controller, serial ports, memory controller, and a PCI/CardBus interface. The NS9775 ARM926EJ-S 32-bit RISC processor core runs at 200 MHz, with 8 kB of instruction cache and 4 kB of data cache.

One of the NS9775's unique features is its four-channel video interface, which supports monochrome, 4-color, and tandem color laser print engines. The video interface is connected directly to four JBIG decompressors that allow simultaneous decompression of four color planes in parallel.

32-bit ARM926EJ-S RISC processor

- 200 MHz
- 5-stage pipeline with interlocking
- Harvard architecture
- 8 kB instruction cache and 4 kB data cache
- 32-bit ARM and 16-bit Thumb instruction sets. Can be mixed for performance/code density tradeoffs.
- MMU to support virtual memory-based OSs, such as Linux, WinCE/Pocket PC, VxWorks, others
- DSP instruction extensions, improved divide, single cycle MAC
- ARM Jazelle, 1200CM (coffee marks) Java accelerator
- EmbeddedICE-RT debug unit
- JTAG boundary scan, BSDL support

Print engine controller

- Four parallel JBIG decoders
  - Internal bypass for uncompressed data
  - Automatic and manual header processing modes
- Glueless interface to most print engines
  - 4 data ports for color tandem printers
  - Single port for 4-pass color printers
  - Single port for monochrome printers

- Up to 13” lines at 2400 dpi
- High print speed:
  - Tandem: 90 ppm
  - 4-pass color: 22 ppm
  - Monochrome: 90 ppm

  These conditions yield the above performance:
  - Page size: 8.5” x 11”
  - Resolution: 600 x 600 dpi
  - Video clock: 100 MHz
  - Horizontal correction factor: 0.7
  - Vertical correction factor: 0.7
- Synchronous print mode with internal PLL
  - Clock rates up to 100 MHz
- Asynchronous print mode with 1or 4 external clocks
  - Clock rates up to 200 MHz
- Bus Master on the system bus and a dedicated 4-channel DMA engine, one per colorplane
- On-chip input and output FIFOs, one pair per color plane
- General communication through serial and GPIO ports

External system bus interface

- 32-bit data, 32-bit internal address bus, 28-bit external address bus
- Glueless interface to SDRAM, SRAM, EEPROM, buffered DIMM, Flash
- 4 static and 4 dynamic memory chip selects
- 0–63 wait states per chip select
- Self-refresh during system sleep mode
- Automatic dynamic bus sizing to 8 bits, 16 bits, 32 bits
- Burst mode support with automatic data width adjustment
- Two external DMA channels for external peripheral support

System Boot

- High-speed boot from 8-bit, 16-bit, or 32-bit ROM or Flash
- Hardware-supported low cost boot from serial EEPROM through SPI port (patent pending)

High performance 10/100 Ethernet MAC

- 10/100 Mbps MII/RMII PHY interfaces
- Full-duplex or half-duplex
- Station, broadcast, or multicast address filtering
- 2 kB RX FIFO
- 256-byte TX FIFO with on-chip buffer descriptor ring
  - Eliminates underruns and decreases bus traffic
- Separate TX and RX DMA channels
- Intelligent receive-side buffer size selection
- Full statistics gathering support
- External CAM filtering support

PCI/CardBus port

- PCI v2.2, 32-bit bus, up to 33 MHz bus speed
- Programmable to:
  - PCI device mode
  - PCI host mode:

    Supports up to 3 external PCI devices

    Embedded PCI arbiter or external arbiter
- CardBus host mode

Flexible LCD controller

- Supports most commercially available displays:
  - Active Matrix color TFT displays:
    Up to 24bpp direct 8:8:8 RGB; 16 colors
  - Single and dual panel color STN displays:
    Up to 16bpp 4:4:4 RGB; 3375 colors
  - Single and dual panel monochrome STN displays:
    1, 2, 4bpp palettized gray scale
- Formats image data and generates timing control signals
- Internal programmable palette LUT and grayscaler support different color techniques
- Programmable panel-clock frequency

USB ports

- USB v.2.0 full speed (12 Mbps) and low speed (1.5 Mbps)
- Configurable to device or OHCI host
  - USB host is bus master
  - USB device supports one bidirectional control endpoint and 11 unidirectional endpoints
- All endpoints supported by a dedicated DMA channel; 13 channels total
- 20 byte RX FIFO and 20 byte TX FIFO

Serial ports

- 4 serial modules, each independently configurable to UART mode, SPI master mode, or SPI slave mode
- Bit rates from 75 bps to 921.6 kbps: asynchronous x16 mode
- Bit rates from 1.2 kbps to 6.25 Mbps: synchronous mode
- UART provides:
  - High-performance hardware and software flow control
  - Odd, even, or no parity
  - 5, 6, 7, or 8 bits
  - 1 or 2 stop bits
  - Receive-side character and buffer gap timers
- Internal or external clock support, digital PLL for RX clock extraction

- 4 receive-side data match detectors
- 2 dedicated DMA channels per module, 8 channels total
- 32 byte TX FIFO and 32 byte RX FIFO per module

I^2C port

- I^2C v.1.0 configurable to master or slave mode
- Bit rates: fast (400 kHz) or normal (100 kHz) with clock stretching
- 7-bit and 10-bit address modes
- Supports I^2C bus arbitration

1284 parallel peripheral port

- All standard modes: ECP, byte, nibble, compatibility (also known as SPP or "Centronix")
- RLE (run length encoding) decoding of compressed data in ECP mode
- Operating clock from 100 kHz to 2 MHz

High performance multiple-master/distributed DMA system

- Intelligent bus bandwidth allocation (patent pending)
- System bus and peripheral bus

System bus

- Every system bus peripheral is a bus master with a dedicated DMA engine

Peripheral bus

- One 13-channel DMA engine supports USB device
  - 2 DMA channels support control endpoint
  - 11 DMA channels support 11 endpoints
- One 12-channel DMA engine supports:
  - 4 serial modules (8 DMA channels)
  - 1284 parallel port (4 DMA channels)
- All DMA channels support fly-by mode

External peripheral

- One 2-channel DMA engine supports external peripheral connected to memory bus
- Each DMA channel supports memory-to-memory transfers

Power management (patent pending)

- Power save during normal operation
  - Disables unused modules
- Power save during sleep mode
  - Sets memory controller to refresh
  - Disables all modules except selected wakeup modules
  - Wakeup on valid packets or characters

Vector interrupt controller

- Decreased bus traffic and rapid interrupt service
- Hardware interrupt prioritization

General purpose timers/counters

- 16 independent 16-bit or 32-bit programmable timers or counters
  - Each with an I/O pin
- Mode selectable into:
  - Internal timer mode
  - External gated timer mode
  - External event counter
- Can be concatenated
- Resolution to measure minute-range events
- Source clock selectable: internal clock or external pulse event
- Each can be individually enabled/disabled

System timers

- Watchdog timer
- System bus monitor timer
- System bus arbiter timer
- Peripheral bus monitor timer

General purpose I/O

- 50 programmable GPIO pins (muxed with other functions)
- Software-readable powerup status registers for every pin for customer-defined bootstrapping

External interrupts

- 4 external programmable interrupts
  - Rising or falling edge-sensitive
  - Low level- or high level-sensitive

Clock generator

- Low cost external crystal
- On-chip phase locked loop (PLL)
- Software programmable PLL parameters
- Optional external oscillator
- Separate PLL for USB

Operating grades/Ambient temperatures

- 200 MHz: 0 – 70^{o} C

System-level interfaces

Figure 1 shows the NS9775 system-level interfaces.

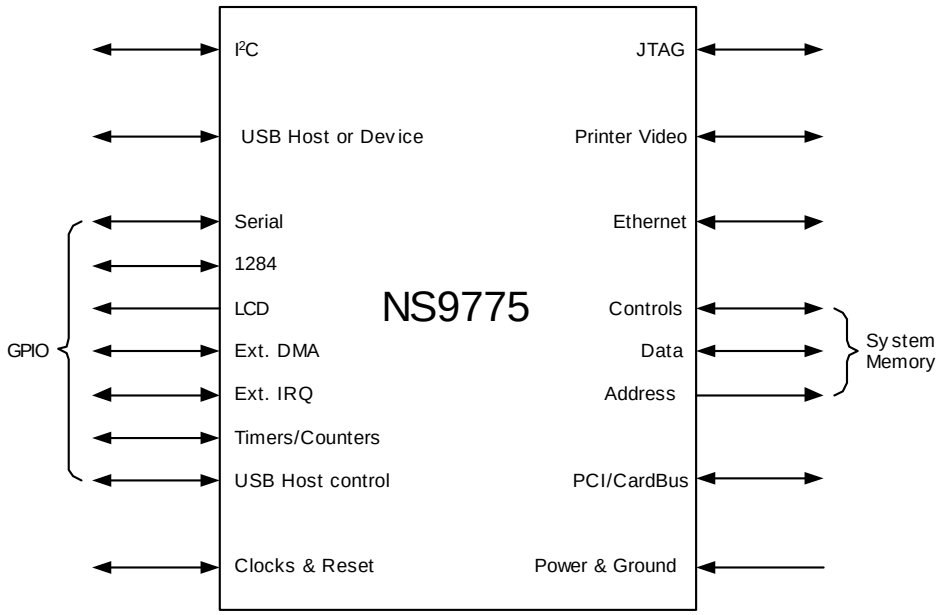


Figure 1: System-level hardware interfaces

- Printer video interface to print engine
- Ethernet MII/RMII interface to external PHY
- System memory interface
  - Glueless connection to SDRAM
  - Glueless connection to buffered PC100 DIMM
  - Glueless connection to SRAM
  - Glueless connection to Flash memory or ROM
- PCI muxed with CardBus interface
- USB host or device interface
- I^2C interface

- 50 GPIO pins muxed with:
  - Four 8-pin-each serial ports, each programmable to UART or SPI
  - 1284 port
  - Up to 24-bit TFT or STN color and monochrome LCD controller
  - Two external DMA channels
  - Four external interrupt pins programmed to rising or falling edge, or to high or low level
  - Sixteen 16-bit or 32-bit programmable timers or counters
  - Two control signals to support USB host
- JTAG development interface
- Clock interfaces for crystal or external oscillator
  - System clock
  - USB clock
  - Printer video clock (used only in asynchronous mode)
- Printer video clock interface for optional print engine clock (used only in synchronous print mode)
- Clock interface for optional LCD external oscillator
- Power and ground

System boot

There are two ways to boot the NS9775 system (see Figure 2):

- From a fast Flash over the system memory bus
- From an inexpensive, but slower, serial EEPROM through SPI port B.

Both boot methods are glueless. The bootstrap pin, RESET_DONE, indicates where to boot on a system powerup. Flash boot can be done from 8-bit, 16-bit, or 32-bit ROM or Flash.

Serial EEPROM boot is supported by NS9775 hardware. A configuration header in the EEPROM specifies total number of words to be fetched from EEPROM, as well as a system memory configuration and a memory controller configuration. The boot engine configures the memory controller and system memory, fetches data from low-cost serial EEPROM, and writes the data to external system memory, holding the CPU in reset.

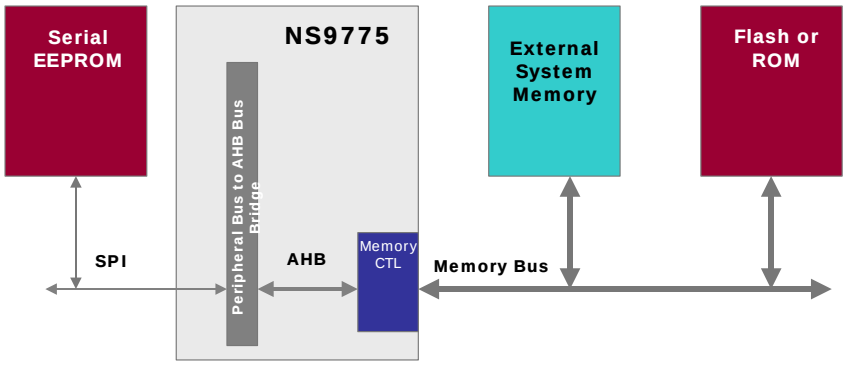


Figure 2: Two methods of booting NS9775 system

Reset

Master reset using an external reset pin resets NS9775. Only the AHB bus error status registers retain their values; software read resets these error status registers. The input reset pin can be driven by a system reset circuit or a simple power-on reset circuit.

RESET_DONE as an input

Used at bootup only:

- When set to 0, the system boots from SDRAM through the serial SPI EEPROM.
- When set to 1, the system boots from Flash/ROM. This is the default.

RESET_DONE as an output

Sets to 1, per Step 6 in the boot sequence.

If the system is booting from serial EEPROM through the SPI port, the boot program must be loaded into the SDRAM before the CPU is released from reset. The memory controller is powered up with `dy_cs_n[0]` enabled with a default set of SDRAM configurations. The default address range for `dy_cs_n[0]` is from `0x0000 0000`. The other chip selects are disabled.

Boot sequence

1. When the system reset turns to inactive, the reset signal to the CPU is still held active.
2. An I/O module on the peripheral bus (BBus) reads from a serial ROM device that contains the memory controller settings and the boot program.
3. The BBus-to-AHB bridge requests and gets the system bus.
4. The memory controller settings are read from the serial EEPROM and used to initialize the memory controller.
5. The BBus-to-AHB bridge loads the boot program into the SDRAM, starting at address 0.
6. The reset signal going to the CPU is released once the boot program is loaded. `RESET_DONE` is now set to 1.
7. The CPU begins to execute code from address `0x0000 0000`.

Figure 3 shows a sample reset circuit.

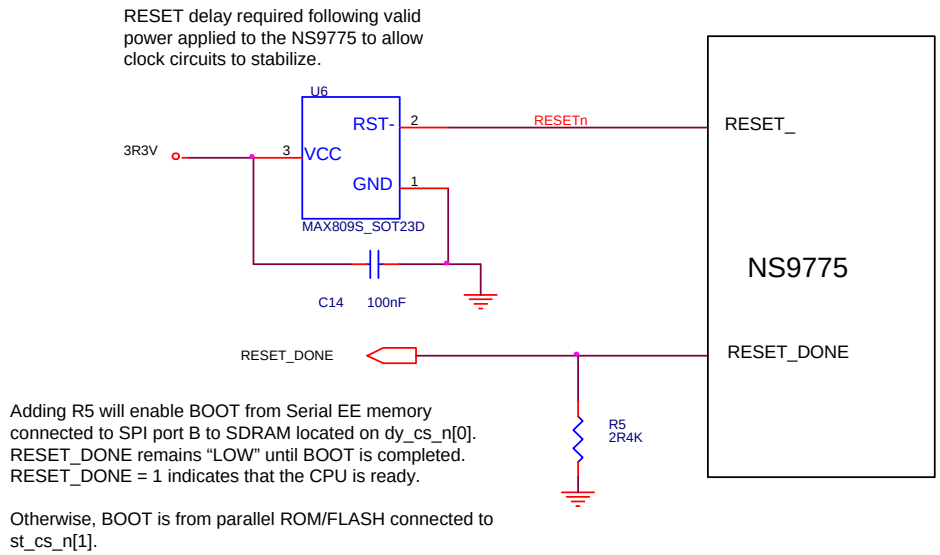


Figure 3: Sample reset circuit

You can use one of five software resets to reset the NS9775. Select the reset by setting the appropriate bit in the appropriate register.

- Watchdog timer can issue reset upon watchdog timer expiration (see "Software Watchdog Timer register" on page 165).
- AHB bus arbiter can issue reset upon AHB bus arbiter timer expiration (see "AHB Bus Arbiter Timeout Period/AHB Bus Monitor Timeout Period register" on page 151).
- AHB bus monitor can issue reset upon AHB bus monitor timer expiration (see "AHB Bus Arbiter Timeout Period/AHB Bus Monitor Timeout Period register" on page 151).
- Software reset can reset individual internal modules or all modules except memory and CPU (see "Reset and Sleep Control register" on page 167).
- The system is reset whenever software sets the PLL SW change bit to 1 (see "PLL Configuration register" on page 171).

Hardware reset duration is 4 ms for PLL to stabilize. Software duration depends on speed grade, as shown in Table 1.

Speed grade	CPU clock cycles	Duration
200 MHz	128	640 ns

Table 1: Software reset duration

The minimum reset pulse width is 10 crystal clocks.

System clock

The system clock is provided to the NS9775 by either a crystal or an external oscillator. Table 2 shows sample clock frequency settings for each chip speed grade.

Speed	cpu_clk	hclk (main bus)	bbus_clk
200 MHz	200 (199.0656)	99.5328	49.7664

Table 2: Sample clock frequency settings with 29.4912 MHz crystal

If an oscillator is used, it must be connected to the `x1_sys_osc` input (C8 pin) on the NS9775. If a crystal is used, it must be connected with a circuit such as the one shown in Figure 4.

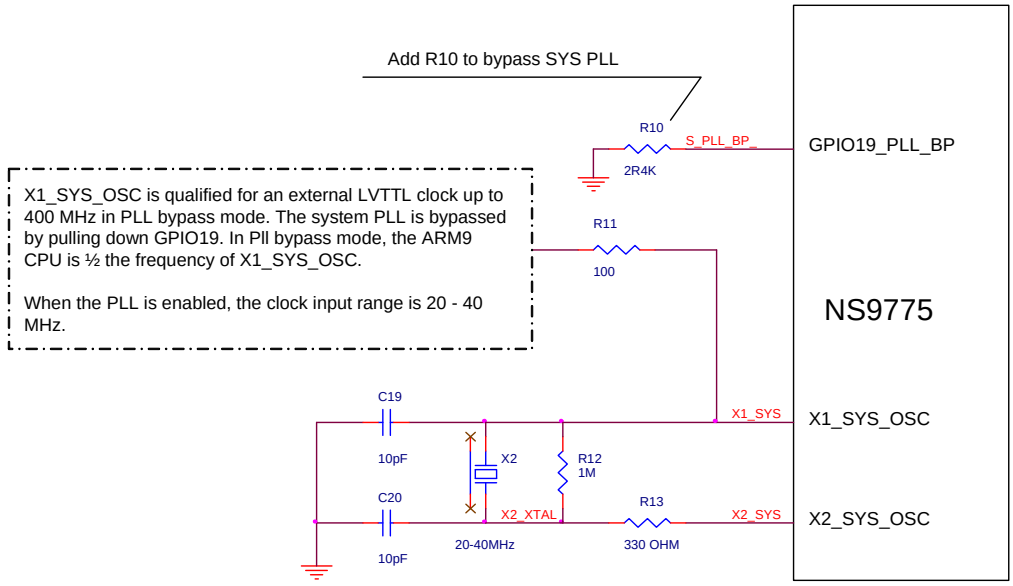


Figure 4: System clock

The PLL parameters are initialized on powerup reset, and can be changed by software from f_{max} to 1/2 f_{max}. This means that the CPU may change from 200 MHz to 100 MHz, the AHB system bus may change from 100 MHz to 50 MHz, and the peripheral BBus may change from 50 MHz to 25 MHz. If changed by software, the system resets automatically after the PLL stabilizes (approximately 4 ms).

The system clock provides clocks for CPU, AHB system bus, peripheral BBus, PCI/CardBus, LCD, timers, memory controller, and BBus modules (serial modules and 1284 parallel port).

The Ethernet MAC uses external clocks from a MII PHY or a RMII PHY. For a MII PHY, these clocks are input signals: `rx_clk` on pin T3 for receive clock and `tx_clk` on pin V3 for transmit clock. For a RMII, there is only one clock, and it connects to the `rx_clk` on pin T3. In this case, the transmit clock, `tx_clk`, should be tied low.

PCI/CardBus, LCD controller, serial modules (UART, SPI), and 1284 port can optionally use external clock signals.

Printer video clock

The printer video module allows the NS9775 to connect to several print engines, including monochrome, four-pass color, and one-pass tandem color print engines. The module can operate in synchronous and asynchronous modes.

The maximum clock rate for synchronous mode is 200 MHz. The maximum clock rate for asynchronous mode is 100 MHz.

- In **synchronous** mode, the external system clock provides the clock that transmits the video bit stream to the print engine. There are four input video clock signals, with programmable active edges. Monochrome and four-pass color print engines use only one clock signal provided by the print engine. The default is the `vclk_0` signal on pin R1. The tandem engines provide either all four clock signals (one per color plane) or one common video clock signal. When using only the single video clock signal from the print engine, the signal must be connected to all four NS9775 input video clock signals.
- In **asynchronous** mode, the NS9775 provides the clock that transmits the video bit stream to the print engine. This clock can be generated by a dedicated internal video PLL and an external crystal, or by an external oscillator. In external oscillator mode, the PLL is bypassed (the default mode). The external oscillator provides the actual video clocks up to 200 MHz when using LV-PECL/LDVS logic. With the PLL enabled, the crystal oscillator range must be between 20 and 440 MHz. The appropriate frequency is selected by using the proper multiplier and divider factors in the PLL.

Figure 5 shows an example of a printer video clock circuit for asynchronous mode of operation. Figure 6 shows the print engine clock generator and the PLL setup table. All multiply and divide factors are programmable.

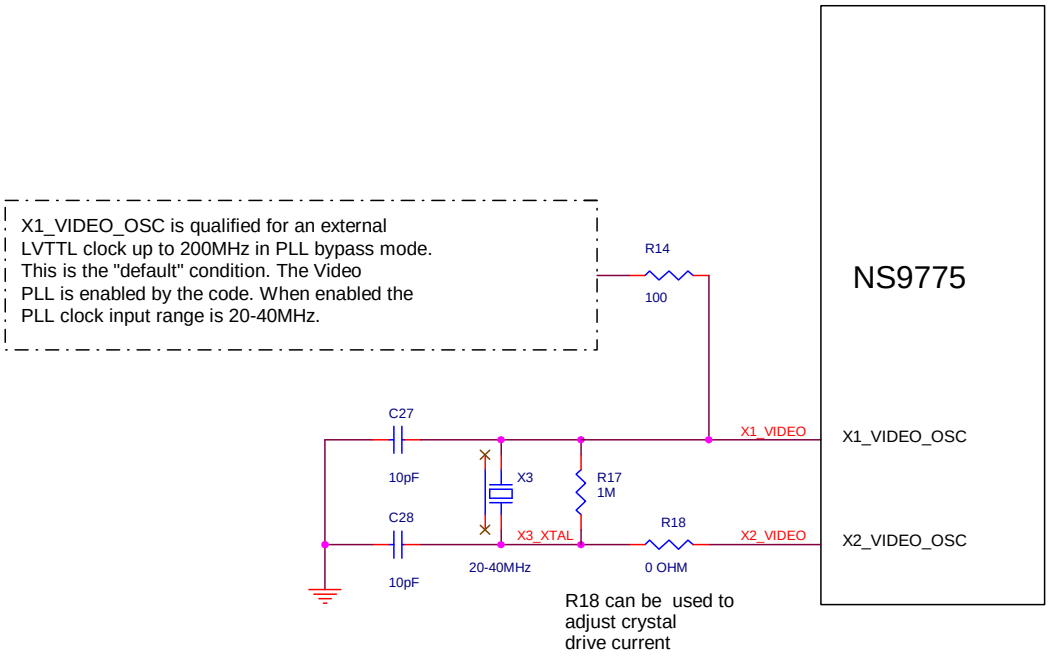
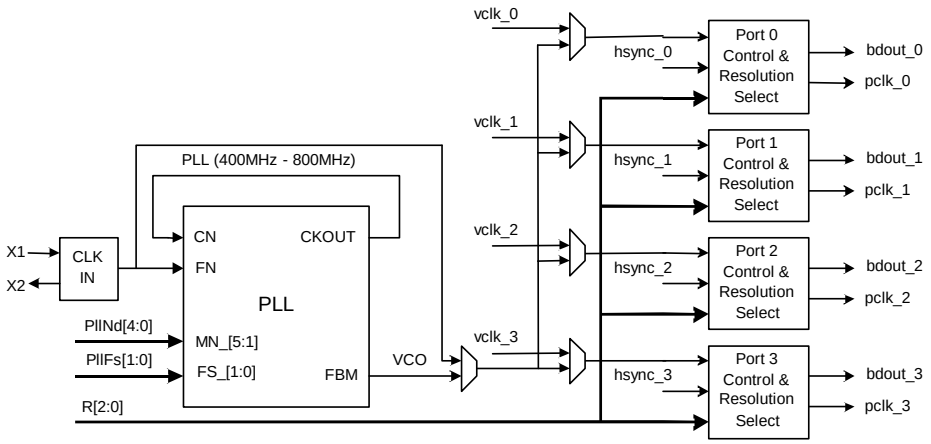


Figure 5: Sample printer video clock circuit for asynchronous operation



PllNd[4:0]	Multiply by
00000	x1
00001	x2
00010	x3
-	-
11111	x32

R[2:0]	Divide by Value
000	16
001	32
010	64
011	128
100	256
101	2
110	4
111	8

FS[1:0]	PLL Div by
00	1
01	2
10	4
11	8

Figure 6: Print engine clock generator and PLL setup table

Print engine clock example

`Vclk = [(Fcrystal x PllNd) / R] / FS`

- Fcrystal = 29.4912 MHz
- PLL is set to multiply by 21(PllNd)
- R is set to divide by 8
- FS is set to divide by 2

`The result is: Vclk = [(29.4912 x 21) / 8] / 2 = 38.7072 MHz`

USB clock

USB is clocked by a separate PLL driven by an external 48 MHz crystal, or it can be driven directly by an external 48 MHz oscillator.

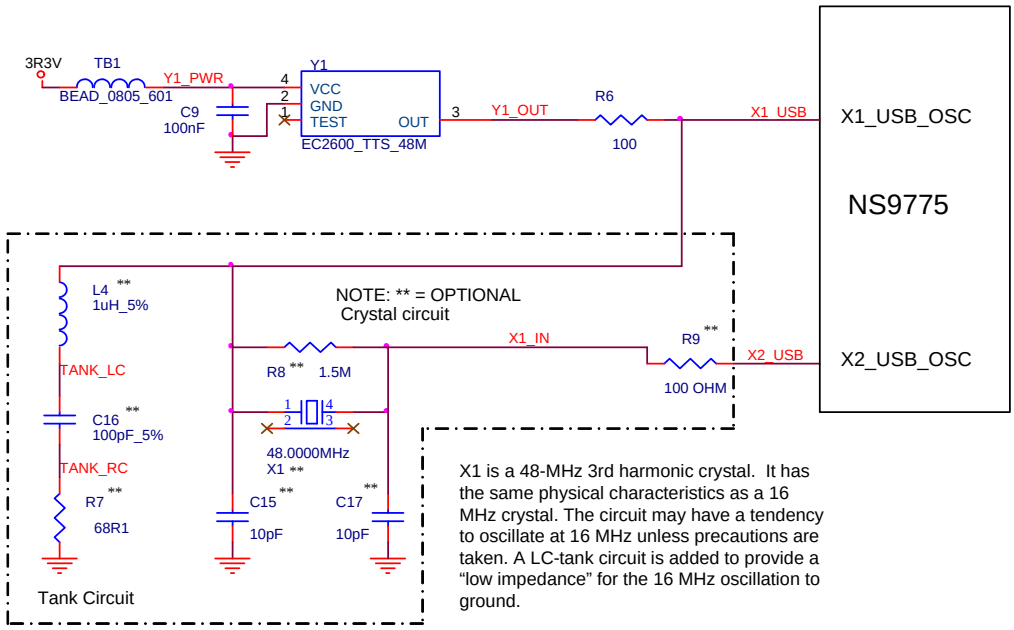


Figure 7: USB clock

NS9775 Pinout

CHAPTER 2

The NS9775 contains most of the major functional components for developing color printer or MFP controllers. All of the major I/Os required in a printer or MFP — Ethernet, USB (host and device), and IEEE 1284 — are provided on-chip. In addition, there are four serial interfaces, and a PCI interface that can be configured for CardBus compatibility. The NS9775 provides up to 50 general purpose I/O (GPIO) pins and configurable power management with sleep mode.

Pinout and signal descriptions

Each pinout table applies to a specific interface, and contains the following information:

Heading	Description
Pin #	Pin number assignment for a specific I/O signal
Signal	Pin name for each I/O signal. Some signals have multiple function modes and are identified accordingly. The mode is configured through firmware using one or more configuration registers. **_n** in the signal name indicates that this signal is active *low*.
U/D	U or D indicates whether the pin is a pullup resistor or a pulldown resistor: ■ **U** — Pullup (input current source) ■ **D** — Pulldown (input current sink) If no value appears, that pin is neither a pullup nor pulldown resistor.
I/O	The type of signal: input, output, or input/output.
OD (mA)	The output drive of an output buffer. NS9775 uses one of three drivers: ■ 2 mA ■ 4 mA ■ 8 mA

More detailed signal descriptions are provided for selected modules.

System Memory interface

Pin #	Signal Name	U/D	OD (mA)	I/O	Description
A21	addr[0]		8	O	Address bus signal
B20	addr[1]		8	O	Address bus signal
C19	addr[2]		8	O	Address bus signal
A20	addr[3]		8	O	Address bus signal
B19	addr[4]		8	O	Address bus signal

Table 3: System Memory interface pinout

Pin #	Signal Name	U/D	OD (mA)	I/O	Description
C18	addr[5]		8	O	Address bus signal
A19	addr[6]		8	O	Address bus signal
A17	addr[7]		8	O	Address bus signal
C16	addr[8]		8	O	Address bus signal
B16	addr[9]		8	O	Address bus signal
A16	addr[10]		8	O	Address bus signal
D15	addr[11]		8	O	Address bus signal
C15	addr[12]		8	O	Address bus signal
B15	addr[13]		8	O	Address bus signal
A15	addr[14]		8	O	Address bus signal
C14	addr[15]		8	O	Address bus signal
B14	addr[16]		8	O	Address bus signal
A14	addr[17]		8	O	Address bus signal
A13	addr[18]		8	O	Address bus signal
B13	addr[19]		8	O	Address bus signal
C13	addr[20]		8	O	Address bus signal
A12	addr[21]		8	O	Address bus signal
B12	addr[22]		8	O	Address bus signal
C12	addr[23]		8	O	Address bus signal
D12	addr[24]		8	O	Address bus signal
A11	addr[25]		8	O	Address bus signal
B11	addr[26]		8	O	Address bus signal
C11	addr[27]		8	O	Address bus signal
G2	clk_en[0]		8	O	SDRAM clock enable
H3	clk_en[1]		8	O	SDRAM clock enable
G1	clk_en[2]		8	O	SDRAM clock enable

Table 3: System Memory interface pinout

Pin #	Signal Name	U/D	OD (mA)	I/O	Description
H2	clk_en[3]		8	O	SDRAM clock enable
A10	clk_out[0]		8	O	SDRAM reference clock. Connect to clk_in[0] using series termination.
A9	clk_out[1]		8	O	SDRAM clock
A5	clk_out[2]		8	O	SDRAM clock
A4	clk_out[3]		8	O	SDRAM clock
G26	data[0]		8	I/O	Data bus signal
H24	data[1]		8	I/O	Data bus signal
G25	data[2]		8	I/O	Data bus signal
F26	data[3]		8	I/O	Data bus signal
G24	data[4]		8	I/O	Data bus signal
F25	data[5]		8	I/O	Data bus signal
E26	data[6]		8	I/O	Data bus signal
F24	data[7]		8	I/O	Data bus signal
E25	data[8]		8	I/O	Data bus signal
D26	data[9]		8	I/O	Data bus signal
F23	data[10]		8	I/O	Data bus signal
E24	data[11]		8	I/O	Data bus signal
D25	data[12]		8	I/O	Data bus signal
C26	data[13]		8	I/O	Data bus signal
E23	data[14]		8	I/O	Data bus signal
D24	data[15]		8	I/O	Data bus signal
C25	data[16]		8	I/O	Data bus signal
B26	data[17]		8	I/O	Data bus signal
D22	data[18]		8	I/O	Data bus signal
C23	data[19]		8	I/O	Data bus signal
B24	data[20]		8	I/O	Data bus signal

Table 3: System Memory interface pinout

Pin #	Signal Name	U/D	OD (mA)	I/O	Description
A25	data[21]		8	I/O	Data bus signal
C22	data[22]		8	I/O	Data bus signal
D21	data[23]		8	I/O	Data bus signal
B23	data[24]		8	I/O	Data bus signal
A24	data[25]		8	I/O	Data bus signal
A23	data[26]		8	I/O	Data bus signal
B22	data[27]		8	I/O	Data bus signal
C21	data[28]		8	I/O	Data bus signal
A22	data[29]		8	I/O	Data bus signal
B21	data[30]		8	I/O	Data bus signal
C20	data[31]		8	I/O	Data bus signal
E1	data_mask[0]		8	O	SDRAM data mask signal
F2	data_mask[1]		8	O	SDRAM data mask signal
G3	data_mask[2]		8	O	SDRAM data mask signal
F1	data_mask[3]		8	O	SDRAM data mask signal
C5	clk_in[0]			I	SDRAM feedback clock. Connect to clk_out[0].
D2	clk_in[1]			I	Connect to GND
E3	clk_in[2]			I	Connect to GND
E2	clk_in[3]			I	Connect to GND
B4	byte_lane_sel_n[0]		8	O	Static memory byte_lane_enable[0] or write_enable_n[0] for byte-wide device signals
F4	byte_lane_sel_n[1]		8	O	Static memory byte_lane_enable[1] or write_enable_n[1] for byte-wide device signals
D1	byte_lane_sel_n[2]		8	O	Static memory byte_lane_enable[2] or write_enable_n[2] for byte-wide device signals

Table 3: System Memory interface pinout

Pin #	Signal Name	U/D	OD (mA)	I/O	Description
F3	byte_lane_sel_n[3]		8	O	Static memory byte_lane_enable[3] or write_enable_n[3] for byte-wide device signals
B5	cas_n		8	O	SDRAM column address strobe
A8	dy_cs_n[0]		8	O	SDRAM chip select signal
B8	dy_cs_n[1]		8	O	SDRAM chip select signal
A6	dy_cs_n[2]		8	O	SDRAM chip select signal
C7	dy_cs_n[3]		8	O	SDRAM chip select signal
C6	st_oe_n		8	O	Static memory output enable
D6	ras_n		8	O	SDRAM row address strobe
H1	dy_pwr_n		8	O	SyncFlash power down
B10	st_cs_n[0]		8	O	Static memory chip select signal
C10	st_cs_n[1]		8	O	Static memory chip select signal
B9	st_cs_n[2]		8	O	Static memory chip select signal
C9	st_cs_n[3]		8	O	Static memory chip select signal
B6	we_n		8	O	SDRAM write enable. Used for static and SDRAM devices.
J3	ta_strb	U		I	Slow peripheral transfer acknowledge

Table 3: System Memory interface pinout

System Memory interface signals

Table 4 describes System Memory interface signals in more detail. All signals are internal to the chip.

Name	I/O	Description
addr[27:0]	O	Address output. Used for both static and SDRAM devices. SDRAM memories use bits [14:0]; static memories use bits [25:0].

Table 4: System Memory interface signal descriptions

Name	I/O	Description
clk_en[3:0]	O	SDRAM clock enable. Used for SDRAM devices. **Note:** The clk_en signals are associated with the dy_cs_n signals.
clk_out[3:1]	O	SDRAM clocks. Used for SDRAM devices.
clk_out[0]	O	SDRAM clk_out[0] is connected to clk_in[0].
data[31:0]	I/O	Read data from memory. Used for the static memory controller and the dynamic memory controller.
data_mask[3:0]	O	Data mask output to SDRAMs. Used for SDRAM devices.
clk_in[3:1]	I	Feedback clocks. Used for SDRAM devices.
clk_in[0]	I	Feedback clock [0]. Always connects to clk_out[0].
byte_lane_sel_n[3:0]	O	Static memory byte_lane_select, active low, or write_enable_n for byte-wide devices.
cas_n	O	Column address strobe. Used for SDRAM devices.
dy_cs_n[3:0]	O	SDRAM chip selects. Used for SDRAM devices.
st_oe_n	O	Output enable for static memories. Used for static memory devices.
ras_n	O	Row address strobe. Used for SDRAM devices.
st_cs_n[3:0]	O	Static memory chip selects. Default active low. Used for static memory devices.
we_n	O	Write enable. Used for SDRAM and static memories.
ta_strb	I	*Slow peripheral transfer acknowledge* can be used to terminate static memory cycles sooner than the number of wait states programmed in the chip select setup register.

Table 4: System Memory interface signal descriptions

Figure 8 shows NS9775 SDRAM clock termination.

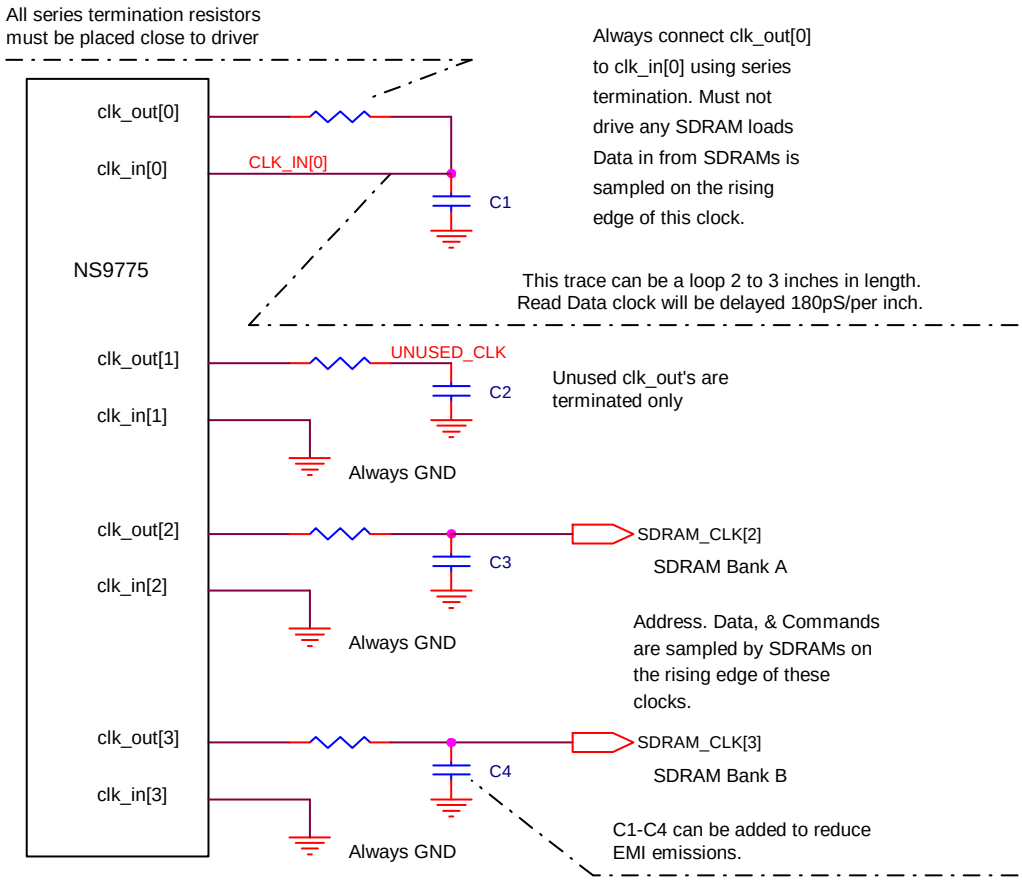


Figure 8: SDRAM clock termination

Ethernet interface

Pin #	Signal name		U/D	OD (mA)	I/O	Description	
	MII	RMII				MII	RMII
AB1	col	N/C			I	Collision	Pull low external to NS9775
AA2	crs	crs_dv			I	Carrier sense	Carrier sense
AC1	enet_phy_int_n	enet_phy_int_n	U		I	Ethernet PHY interrupt	Ethernet PHY interrupt
AA3	mdc	mdc		4	O	MII management interface clock	MII management interface clock
AB2	mdio	mdio	U	2	I/O	MII management data	MII management data
T3	rx_clk	ref_clk			I	Receive clock	Reference clock
V2	rx_dv	N/C			I	Receive data valid	Pull low external to NS9775
W1	rx_er	rx_er			I	Receive error	Optional signal; pull low to NS9775 if not used
V1	rxd[0]	rxd[0]			I	Receive data bit 0	Receive data bit 0
U3	rxd[1]	rxd[1]			I	Receive data bit 1	Receive data bit 1
U2	rxd[2]	N/C			I	Receive data bit 2	Pull low external to NS9775
U1	rxd[3]	N/C			I	Receive data bit 3	Pull low external to NS9775
V3	tx_clk	N/C			I	Transmit clock	Pull low external to NS9775
AA1	tx_en	tx_en		2	O	Transmit enable	Transmit enable
Y3	tx_er	N/C		2	O	Transmit error	N/A
Y2	txd[0]	txd[0]		2	O	Transmit data bit 0	Transmit data bit 0
W3	txd[1]	txd[1]		2	O	Transmit data bit 1	Transmit data bit 1

Table 5: Ethernet interface pinout

Pin #	Signal name		U/D	OD (mA)	I/O	Description	
	MII	RMII				MII	RMII
Y1	txd[2]	N/C		2	O	Transmit data bit 2	N/A
W2	txd[3]	N/C		2	O	Transmit data bit 3	N/A

Table 5: Ethernet interface pinout

Clock generation/system pins

Pin #	Signal name	U/D	OD (mA)	I/O	Description
C8	x1_sys_osc			I	System clock crystal oscillator circuit input
B7	x2_sys_osc			O	System clock crystal oscillator circuit output
D9	x1_usb_osc			I	USB clock crystal oscillator circuit input. (Connect to GND if USB is not used.)
A7	x2_usb_osc			O	USB clock crystal oscillator circuit output
AC21	reset_done	U	2	I/O	CPU is enabled once the boot program is loaded. Reset_done is set to 1.
H25	reset_n	U		I	System reset input signal
AD20	bist_en_n			I	Enable internal BIST operation
AF21	pll_test_n			I	Enable PLL testing
AE21	scan_en_n			I	Enable internal scan testing
B18	sys_pll_dvdd				System clock PLL 1.5V digital power
A18	sys_pll_dvss				System clock PLL digital ground
B17	sys_pll_avdd				System clock PLL 3.3V analog power
C17	sys_pll_avss				System clock PLL analog ground
J2	lcdclk	U		I	External LCD clock input

Table 6: Clock generation and system pin pinout

Pin #	Signal name	U/D	OD (mA)	I/O	Description
T2	print_out	U	2	I/O	Chip select 1 static memory byte_lane_enable_n, or write_enable_n for byte-wide devices
N3	bp_stat[0]	U	2	I/O	CardBus mode
P1	bp_stat[1]	U	2	I/O	Memory interface read mode
P2	bp_stat[2]	U	2	I/O	Chip select 1 data width
P3	bp_stat[3]	U	2	I/O	Chip select 1 data width
AF6	x1_vid_osc			I	Video clock crystal oscillator circuit input. (Connect to GND if video crystal oscillator is not used.)
AE7	x2_vid_osc			O	Video clock crystal oscillator circuit output
AD4	vid_pll_dvdd				Video clock PLL 1.5V digital power
AC5	vid_pll _dvss				Video clock PLL digital ground
AF2	vid_pll_avdd				Video clock PLL 3.3V analog power
AE3	vid_pll_avss				Video clock PLL analog ground

Table 6: Clock generation and system pin pinout

bist_en_n, pll_test_n, and scan_en_n

Table 7 is a truth/termination table for `bist_en_n`, `pll_test_n`, and `scan_en_n`.

	Normal operation	ARM debug	
pll_test_n	pull up	pull up	10K recommended
bist_en_n	pull down	pull up	10K pullup = debug 2.4K pulldown = normal
scan_en_n	pull down	pull down	2.4K recommended

Table 7: bist_en_n, pll_test_n, & scan_en_n truth/termination table

PCI interface

The PCI interface can be set to PCI host or PCI device (slave) using the `pci_central_rsc_n` pin.

Note: All output drivers for PCI meet the standard PCI driver specification.

Pin #	Signal name	U/D	OD (mA)	I/O	Description
J24	ad[0][1]		N/A	I/O	PCI time-multiplexed address/data bus
H26	ad[1][1]		N/A	I/O	PCI time-multiplexed address/data bus
J25	ad[2][1]		N/A	I/O	PCI time-multiplexed address/data bus
J26	ad[3][1]		N/A	I/O	PCI time-multiplexed address/data bus
K24	ad[4][1]		N/A	I/O	PCI time-multiplexed address/data bus
K25	ad[5][1]		N/A	I/O	PCI time-multiplexed address/data bus
K26	ad[6][1]		N/A	I/O	PCI time-multiplexed address/data bus
L24	ad[7][1]		N/A	I/O	PCI time-multiplexed address/data bus
L26	ad[8][1]		N/A	I/O	PCI time-multiplexed address/data bus
M24	ad[9][1]		N/A	I/O	PCI time-multiplexed address/data bus
M25	ad[10][1]		N/A	I/O	PCI time-multiplexed address/data bus
M26	ad[11][1]		N/A	I/O	PCI time-multiplexed address/data bus
N24	ad[12][1]		N/A	I/O	PCI time-multiplexed address/data bus
N25	ad[13][1]		N/A	I/O	PCI time-multiplexed address/data bus
N26	ad[14][1]		N/A	I/O	PCI time-multiplexed address/data bus
P26	ad[15][1]		N/A	I/O	PCI time-multiplexed address/data bus
U24	ad[16][1]		N/A	I/O	PCI time-multiplexed address/data bus
V26	ad[17][1]		N/A	I/O	PCI time-multiplexed address/data bus
V25	ad[18][1]		N/A	I/O	PCI time-multiplexed address/data bus
W26	ad[19][1]		N/A	I/O	PCI time-multiplexed address/data bus
V24	ad[20][1]		N/A	I/O	PCI time-multiplexed address/data bus
W25	ad[21][1]		N/A	I/O	PCI time-multiplexed address/data bus

Table 8: PCI interface pinout

Pin #	Signal name	U/D	OD (mA)	I/O	Description
Y26	ad[22][1]		N/A	I/O	PCI time-multiplexed address/data bus
W24	ad[23][1]		N/A	I/O	PCI time-multiplexed address/data bus
Y24	ad[24][1]		N/A	I/O	PCI time-multiplexed address/data bus
AA25	ad[25][1]		N/A	I/O	PCI time-multiplexed address/data bus
AB26	ad[26][1]		N/A	I/O	PCI time-multiplexed address/data bus
AA24	ad[27][1]		N/A	I/O	PCI time-multiplexed address/data bus
AB25	ad[28][1]		N/A	I/O	PCI time-multiplexed address/data bus
AC26	ad[29][1]		N/A	I/O	PCI time-multiplexed address/data bus
AD26	ad[30][1]		N/A	I/O	PCI time-multiplexed address/data bus
AC25	ad[31][1]		N/A	I/O	PCI time-multiplexed address/data bus
L25	cbe_n[0][1]		N/A	I/O	Command/byte enable
P25	cbe_n[1][1]		N/A	I/O	Command/byte enable
U25	cbe_n[2][1]		N/A	I/O	Command/byte enable
AA26	cbe_n[3][1]		N/A	I/O	Command/byte enable
T26	devsel_n[2]		N/A	I/O	Device select
U26	frame_n[2]		N/A	I/O	Cycle frame
Y25	idsel[3, 4]		N/A	I	Initialization device select: ■ For PCI host applications, connect to AD11. ■ For PCI device applications, connection is determined by the PCI device number assigned to the NS9775. ■ For CardBus applications, connect to the external pullup resistor. ■ Do not allow input to float in any application.
T24	irdy_n[2]		N/A	I/O	Initiator ready
P24	par[1]		N/A	I/O	Parity signal

Table 8: PCI interface pinout

Pin #	Signal name	U/D	OD (mA)	I/O	Description
R25	perr_n[2]		N/A	I/O	Parity error
R26	serr_n[2]		N/A	I/O	System error Input: `pci_central_resource_n = 0` Output: `pci_central_resource_n = 1`
R24	stop_n[2]		N/A	I/O	Stop signal
T25	trdy_n[2]		N/A	I/O	Target ready
AC24	pci_arb_gnt_1_n[6]		N/A	O	PCI channel 1 grant
AD23	pci_arb_gnt_2_n[6]		N/A	O	PCI channel 2 grant
AE24	pci_arb_gnt_3_n[6]		N/A	O	PCI channel 3 grant
AD25	pci_arb_req_1_n[2]		N/A	I	PCI channel 1 request
AB23	pci_arb_req_2_n[2]		N/A	I	PCI channel 2 request
AC22	pci_arb_req_3_n[2]		N/A	I	PCI channel 3 request
AF23	pci_central_resource_n	D	N/A	I	PCI internal central resource enable
AF25	pci_int_a_n[2]		N/A	I/O	PCI interrupt request A, output if external central resource used
AF24	pci_int_b_n[2]		N/A	I/O	PCI interrupt request B, CCLKRUN# for CardBus applications
AE23	pci_int_c_n[2]		N/A	I	PCI interrupt request C
AD22	pci_int_d_n[2]		N/A	I	PCI interrupt request D
AE26	pci_reset_n[3]		N/A	I/O	PCI reset, output if internal central resource enabled
AB24	pci_clk_in	U	N/A	I	PCI clock in. (Connected to pci_clk_out or an externally generated PCI reference clock.)
AA23	pci_clk_out		N/A	O	PCI clock out

Table 8: PCI interface pinout

PCI/CardBus signals

Most of the CardBus signals are the same as the PCI signals. Other CardBus signals are unique and multiplexed with PCI signals for the NS9775. Table 9 shows these unique signals. Figure 9 illustrates how to terminate an unused PCI.

PCI signal	CardBus signal	CardBus type	Description
INTA#	CINT#[4]	Input	CardBus interrupt pin. The INTA2PCI pin in the PCI Miscellaneous Support register must be set to 0.
INTB#	CCLKRUN#[4]	Bidir	CardBus pin used to negotiate with the external CardBus device before stopping the clock. Allows external CardBus device to request that the clock be restarted.
INTC#	CSTSCHG[5]	Input	CardBus status change interrupt signal.
GNT1#	CGNT#[4]	Output	Grant to external CardBus device from NS9775's internal arbiter.
GNT2#	CVS1	Output	Voltage sense pin. Normally driven low by NS9775, but toggled during the interrogation of the external CardBus device to find voltage requirements. **Note:** Do not connect directly to the CardBus connector. See the diagram "CardBus system connections to NS9775" on page 475 for a suggested connection scheme.
GNT3#	CVS2	Output	Voltage sense pin. Normally driven low by NS9775, but toggled during the interrogation of the external CardBus device to find voltage requirements.
REQ1#	CREQ#[4]	Input	Request from external CardBus device to NS9775's internal arbiter.
REQ2#	CCD1[4]	Input	Card detect pin. Pulled up when the socket is empty and pulled low when the external CardBus device is in the socket.

Table 9: CardBus IO multiplexed signals

PCI signal	CardBus signal	CardBus type	Description
REQ3#	CCD2[4]	Input	Card detect pin. Pulled up when the socket is empty and pulled low when the external CardBus device is in the socket.

Table 9: CardBus IO multiplexed signals

Notes:

1 Add external pulldown resistor *only* if the PCI interface is not being used. See the discussion of PCI bridge configuration in *Sample Driver Configurations* for information about eliminating the pulldown resistor.

2 Add external pullup resistors *regardless* of whether the PCI interface is being used.

3 Add external pullup resistor *only* if the PCI interface is not being used.

4 Add external pullup resistor in CardBus mode.

5 Add external pulldown resistor in CardBus mode.

6 Add external pullup only if the PCI interface is being used and this signal is also being used.

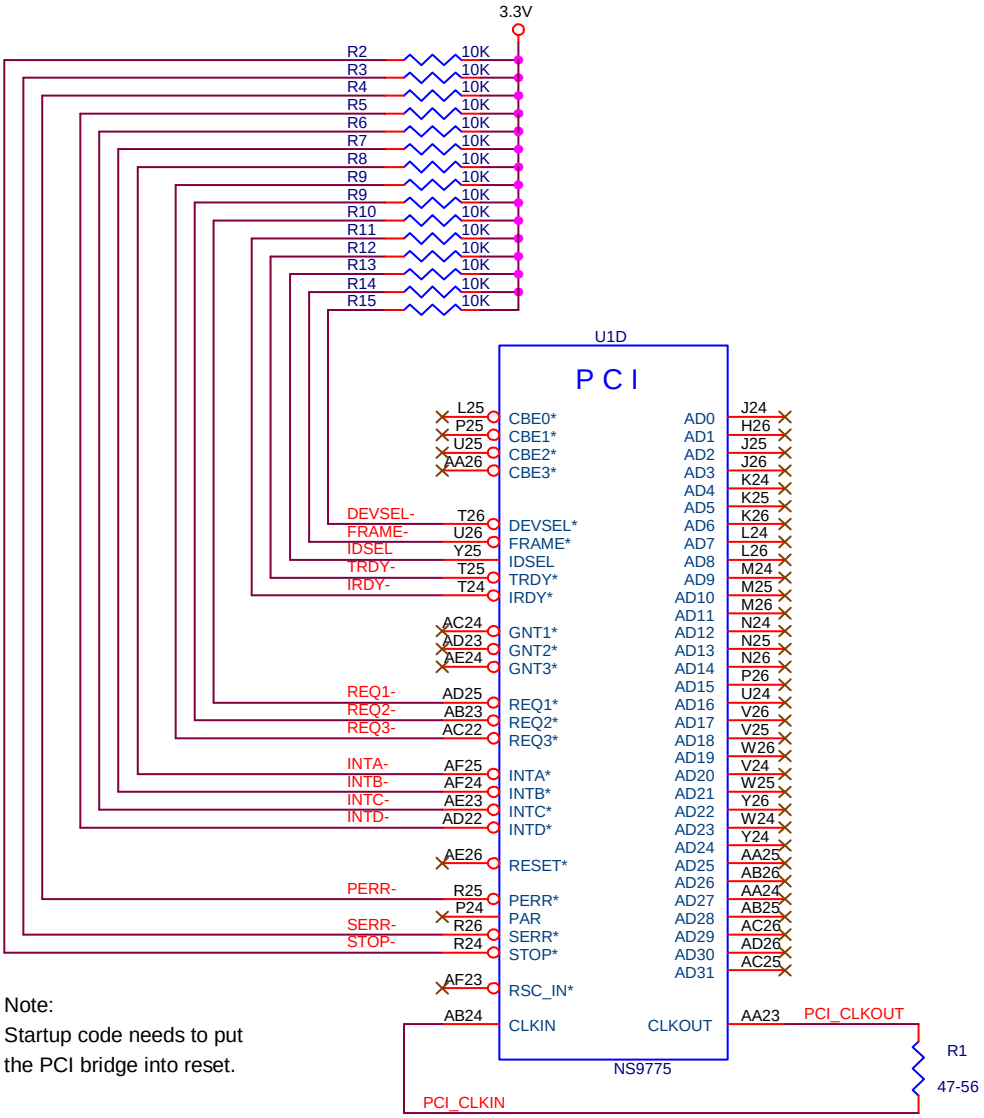


Figure 9: NS9775 unused PCI termination

GPIO MUX

Note: The BBus utility contains the control pins for each GPIO MUX bit. Each pin can be selected individually; that is, you can select any option (00, 01, 02, 03) for any pin, by setting the appropriate bit in the appropriate register. Some signals are muxed to two different GPIO pins, to maximize the number of possible applications. These duplicate signals are marked as such in the Descriptions column in the table.

The 00 option for the serial ports (B, A, C, and D) are configured for UART and SPI mode, respectively; that is, the UART option is shown first, followed by the SPI option if there is one. If only one value appears, it is the UART value. SPI options all begin with *SPI*.

Pin #	Signal name	U/D	OD (mA)	I/O	Description (4 options: 00, 01, 02, 03)	
AF19	gpio[0]	U	2	I/O	00	Ser port B TxData / SPI port B dout
					01	DMA ch 1 done (duplicate)
					02	Timer 1 (duplicate)
					03	GPIO 0
AE18	gpio[1]	U	2	I/O	00	Ser port B RxData / SPI port B din
					01	DMA ch 1 req (duplicate)
					02	Ext IRQ 0
					03	GPIO 1
AF18	gpio [2]	U	2	I/O	00	Ser port B RTS
					01	Timer 0
					02	DMA ch 2 read enable
					03	GPIO 2
AD17	gpio[3]	U	2	I/O	00	Ser port B CTS
					01	1284 nACK (peripheral-driven)
					02	DMA ch 1 req
					03	GPIO 3
AE17	gpio[4]	U	2	I/O	00	Ser port B DTR
					01	1284 busy (peripheral-driven)
					02	DMA ch 1 done
					03	GPIO 4

Table 10: GPIO MUX pinout

Pin #	Signal name	U/D	OD (mA)	I/O	Description (4 options: 00, 01, 02, 03)	
AF17	gpio[5]	U	2	I/O	00	Ser port B DSR
					01	1284 PError (peripheral-driven)
					02	DMA ch 1 read enable
					03	GPIO 5
AD16	gpio[6]	U	2	I/O	00	Ser port B RI / SPI port B clk
					01	1284 nFault (peripheral-driven)[1]
					02	Timer 7 (duplicate)
					03	GPIO 6
AE16	gpio[7]	U	2	I/O	00	Ser port B DCD / SPI port B enable
					01	DMA ch 1 read enable (duplicate)
					02	Ext IRQ 1
					03	GPIO 7
AD15	gpio[8]	U	2	I/O	00	Ser port A TxData / SPI port A dout
					01	Reserved
					02	Reserved
					03	GPIO 8
AE15	gpio[9]	U	2	I/O	00	Ser port A RxData / SPI port A din
					01	Reserved
					02	Timer 8 (duplicate)
					03	GPIO 9
AF15	gpio[10]	U	2	I/O	00	Ser port A RTS
					01	Reserved
					02	Reserved
					03	GPIO 10
AD14	gpio[11]	U	2	I/O	00	Ser port A CTS
					01	Ext IRQ2 (duplicate)
					02	Timer 0 (duplicate)
					03	GPIO 11
AE14	gpio[12]	U	2	I/O	00	Ser port A DTR
					01	Reserved
					02	Reserved
					03	GPIO 12

Table 10: GPIO MUX pinout

Pin #	Signal name	U/D	OD (mA)	I/O	Description (4 options: 00, 01, 02, 03)	
AF14	gpio[13]	U	2	I/O	00	Ser port A DSR
					01	Ext IRQ 0 (duplicate)
					02	Timer 10 (duplicate)
					03	GPIO 13
AF13	gpio[14]	U	2	I/O	00	Ser port A RI / SPI port A clk
					01	Timer 1
					02	Reserved
					03	GPIO 14
AE13	gpio[15]	U	2	I/O	00	Ser port A DCD / SPI port A enable
					01	Timer 2
					02	Reserved
					03	GPIO 15
AD13	gpio[16]	U	2	I/O	00	Reserved
					01	1284 nFault (peripheral-driven, duplicate)[1]
					02	Timer 11 (duplicate)
					03	GPIO 16
AF12	gpio[17]	U	2	I/O	00	USB power relay
					01	Reserved
					02	Reserved
					03	GPIO 17
AE12	gpio[18]	U	4	I/O	00	Ethernet CAM reject
					01	LCD power enable
					02	Ext IRQ 3 (duplicate)
					03	GPIO 18
AD12	gpio[19]	U	4	I/O	00	Ethernet CAM req
					01	LCD line-horz sync
					02	DMA ch 2 read enable (duplicate)
					03	GPIO 19
AC12	gpio[20]	U	8	I/O	00	Ser port C DTR
					01	LCD clock
					02	Reserved
					03	GPIO 20

Table 10: GPIO MUX pinout

Pin #	Signal name	U/D	OD (mA)	I/O	Description (4 options: 00, 01, 02, 03)	
AF11	gpio[21]	U	4	I/O	00	Ser port C DSR
					01	LCD frame pulse-vert
					02	Reserved
					03	GPIO 21
AE11	gpio[22]	U	4	I/O	00	Ser port C RI / SPI port C clk
					01	LCD AC bias-data enable
					02	Reserved
					03	GPIO 22
AD11	gpio[23]	U	4	I/O	00	Ser port C DCD / SPI port C enable
					01	LCD line end
					02	Timer 14 (duplicate)
					03	GPIO 23
AF10	gpio[24]	U	4	I/O	00	Ser port D DTR
					01	LCD data bit 0
					02	Reserved
					03	GPIO 24
AE10	gpio[25]	U	4	I/O	00	Ser port D DSR
					01	LCD data bit 1
					02	Timer 15 (duplicate)
					03	GPIO 25
AD10	gpio[26]	U	4	I/O	00	Ser port D RI / SPI port D clk
					01	LCD data bit 2
					02	Timer 3
					03	GPI0 26
AF9	gpio[27]	U	4	I/O	00	Ser port D DCD / SPI port D enable
					01	LCD data bit 3
					02	Timer 4
					03	GPIO 27
AE9	gpio[28]	U	4	I/O	00	Ext IRQ 1 (duplicate)
					01	LCD data bit 4
					02	LDC data bit 8 (duplicate)
					03	GPIO 28

Table 10: GPIO MUX pinout

Pin #	Signal name	U/D	OD (mA)	I/O	Description (4 options: 00, 01, 02, 03)	
AF8	gpio[29]	U	4	I/O	00	Timer 5
					01	LCD data bit 5
					02	LCD data bit 9 (duplicate)
					03	GPIO 29
AD9	gpio[30]	U	4	I/O	00	Timer 6
					01	LCD data bit 6
					02	LCD data bit 10 (duplicate)
					03	GPIO 30
AE8	gpio[31]	U	4	I/O	00	Timer 7
					01	LCD data bit 7
					02	LCD data bit 11 (duplicate)
					03	GPIO 31
AF7	gpio[32]	U	4	I/O	00	Ext IRQ 2
					01	1284 Data 1 (bidirectional)
					02	LCD data bit 8
					03	GPIO 32
AD8	gpio[33]	U	4	I/O	00	Timer 8
					01	1284 Data 2 (bidirectional)
					02	LCD data bit 9
					03	GPIO 33
AD7	gpio[34]	U	4	I/O	00	Timer 9
					01	1284 Data 3 (bidirectional)
					02	LCD data bit 10
					03	GPIO 34
AE6	gpio[35]	U	4	I/O	00	Timer 10
					01	1284 Data 4 (bidirectional)
					02	LCD data bit 11
					03	GPIO 35
AF5	gpio[36]	U	4	I/O	00	Reserved
					01	1284 Data 5 (bidirectional)
					02	LCD data bit 12
					03	GPIO 36

Table 10: GPIO MUX pinout

Pin #	Signal name	U/D	OD (mA)	I/O	Description (4 options: 00, 01, 02, 03)	
AD6	gpio[37]	U	4	I/O	00	Reserved
					01	1284 Data 6 (bidirectional)
					02	LCD data bit 13
					03	GPIO 37
AE5	gpio[38]	U	4	I/O	00	Reserved
					01	1284 Data 7 (bidirectional)
					02	LCD data bit 14
					03	GPIO 38
AF4	gpio[39]	U	4	I/O	00	Reserved
					01	1284 Data 8 (bidirectional)
					02	LCD data bit 15
					03	GPIO 39
AC6	gpio[40]	U	4	I/O	00	Ser port C TxData / SPI port C dout
					01	Ext IRQ 3
					02	LCD data bit 16
					03	GPIO 40
AD5	gpio[41]	U	4	I/O	00	Ser port C RxData / SPI port C din
					01	Timer 11
					02	LCD data bit 17
					03	GPIO 41
AE4	gpio[42]	U	4	I/O	00	Ser port C RTS
					01	Timer 12
					02	LCD data bit 18
					03	GPIO 42
AF3	gpio[43]	U	4	I/O	00	Ser port C CTS
					01	Timer 13
					02	LCD data bit 19
					03	GPIO 43
AD2	gpio[44]	U	4	I/O	00	Ser port D TxData / SPI port D dout
					01	1284 Select (peripheral-driven)
					02	LCD data bit 20
					03	GPIO 44

Table 10: GPIO MUX pinout

Pin #	Signal name	U/D	OD (mA)	I/O	Description (4 options: 00, 01, 02, 03)	
AE1	gpio[45]	U	4	I/O	00	Ser port D RxData / SPI port D din
					01	1284 nStrobe (host-driven)
					02	LCD data bit 21
					03	GPIO 45
AB3	gpio[46]	U	4	I/O	00	Ser port D RTS
					01	1284 nAutoFd (host-driven)
					02	LCD data bit 22
					03	GPIO 46
AA4	gpio[47]	U	4	I/O	00	Ser port D CTS
					01	1284 nInit (host-driven)
					02	LCD data bit 23
					03	GPIO 47
AC2	gpio[48]	U	2	I/O	00	Timer 14
					01	1284 nSelectIn (host-driven)
					02	DMA ch 2 req
					03	GPIO 48
AD1	gpio[49]	U	2	I/O	00	Timer 15
					01	1284 peripheral logic high (peripheral-driven)
					02	DMA ch 2 done
					03	GPIO 49

Table 10: GPIO MUX pinout

Note:

1 The `nFault` signal GPIO6 or GPIO16 can be used as a code-controlled direction pin for the transceiver. The polarity cannot be altered inside the NS9775; an inverter will be required.

LCD module signals

The LCD module signals are multiplexed with GPIO pins. They include seven control signals and up to 24 data signals. Table 11 describes the control signals.

Signal name	Type	Description
CLPOWER	Output	LCD panel power enable
CLLP	Output	Line synchronization pulse (STN) / horizontal synchronization pulse (TFT)
CLCP	Output	LCD panel clock
CLFP	Output	Frame pulse (STN) / vertical synchronization pulse (TFT)
CLAC	Output	STN AC bias drive or TFT data enable output
CLD[23:0]	Output	LCD panel data
CLLE	Output	Line end signal

Table 11: LCD module signal descriptions

The `CLD[23:0]` signal has eight modes of operation:

- TFT 24-bit interface
- TFT 18-bit interface
- Color STN single panel
- Color STN dual panel
- 4-bit mono STN single panel
- 4-bit mono STN dual panel
- 8-bit mono STN single panel
- 8-bit mono STN dual panel

See the discussion of LCD panel signal multiplexing details for information about the `CLD` signals used with STN and TFT displays.

Printer engine interface

Pin #	Signal name	U/D	OD (mA)	I/O	Description
N3	bp_stat_0	U	2	I/O	Channel 0 bypass status bit 1

Table 12: Print engine interface (JBIG video) pinout

Pin #	Signal name	U/D	OD (mA)	I/O	Description
P1	bp_stat_1	U	2	I/O	Channel 1 bypass status bit 1
P2	bp_stat_2	U	2	I/O	Channel 2 bypass status bit 2
P3	bp_stat_3	U	2	I/O	Channel 3 bypass status bit 1
J1	hsync_0			I	Channel 0 horizontal sync
K3	hsync_1			I	Channel 1 horizontal sync
K2	hsync_2			I	Channel 2 horizontal sync
K1	hsync_3			I	Channel 3 horizontal sync
M2	vsync_0		2	I/O	Channel 0 vertical sync / Channel 0 bypass status bit 0
M1	vsync_1		2	I/O	Channel 1 vertical sync / Channel 1 bypass status bit 0
N1	vsync_2		2	I/O	Channel 2 vertical sync / Channel 2 bypass status bit 0
N2	vsync_3		2	I/O	Channel 3 vertical sync / Channel 3 bypass status bit 0
R1	vclk_0			I	Channel 0 video clock
R2	vclk_1			I	Channel 1 video clock
R3	vclk_2			I	Channel 2 video clock
T1	vclk_3			I	Channel 3 video clock
L3	video_data_0		8	O	Channel 0 serial video data
L2	video_data_1		8	O	Channel 1 serial video data
L1	video_data_2		8	O	Channel 2 serial video data
M3	video_data_3		8	O	Channel 3 serial video data
T2	print	U	2	I/O	Print control output

Table 12: Print engine interface (JBIG video) pinout

I²C interface

Bits	Signal name	U/D	OD (mA)	I/O	Description
AC15	iic_scl		4	I/O	I²C serial clock line. Add a 10K resistor to VDDA(3.3V) if not used.
AF16	iic_sda		4	I/O	I²C serial data line. Add a 10K resistor to VDDA(3.3V) if not used.

Table 13: I²C interface pinout

USB interface

Notes:

- If not using the USB interface, these pins should be pulled down to ground through a 15K ohm resistor.
- All output drivers for USB meet the standard USB driver specification.

Bits	Signal name	U/D	OD (mA)	I/O	Description
AB4	usb_dm			I/O	USB data -
AC3	usb_dp			I/O	USB data +

Table 14: USB interface pinout

JTAG interface for ARM core/boundary scan

Note: `trst_n` must be pulsed low to initialize JTAG when a debugger is not attached. See Figure 10, "JTAG interface," on page 48.

Bits	Signal name	U/D	OD (mA)	I/O	Description
AE20	tck			I	Test clock
AD18	tdi	U		I	Test data in

Table 15: JTAG interface/boundary scan pinout

Bits	Signal name	U/D	OD (mA)	I/O	Description
AE19	tdo		2	O	Test data out
AC18	tms	U		I	Test mode select
AF20	trst_n	U		I	Test mode reset
AD19	rtck	U	2	I/O	Returned test clock, ARM core only

Table 15: JTAG interface/boundary scan pinout

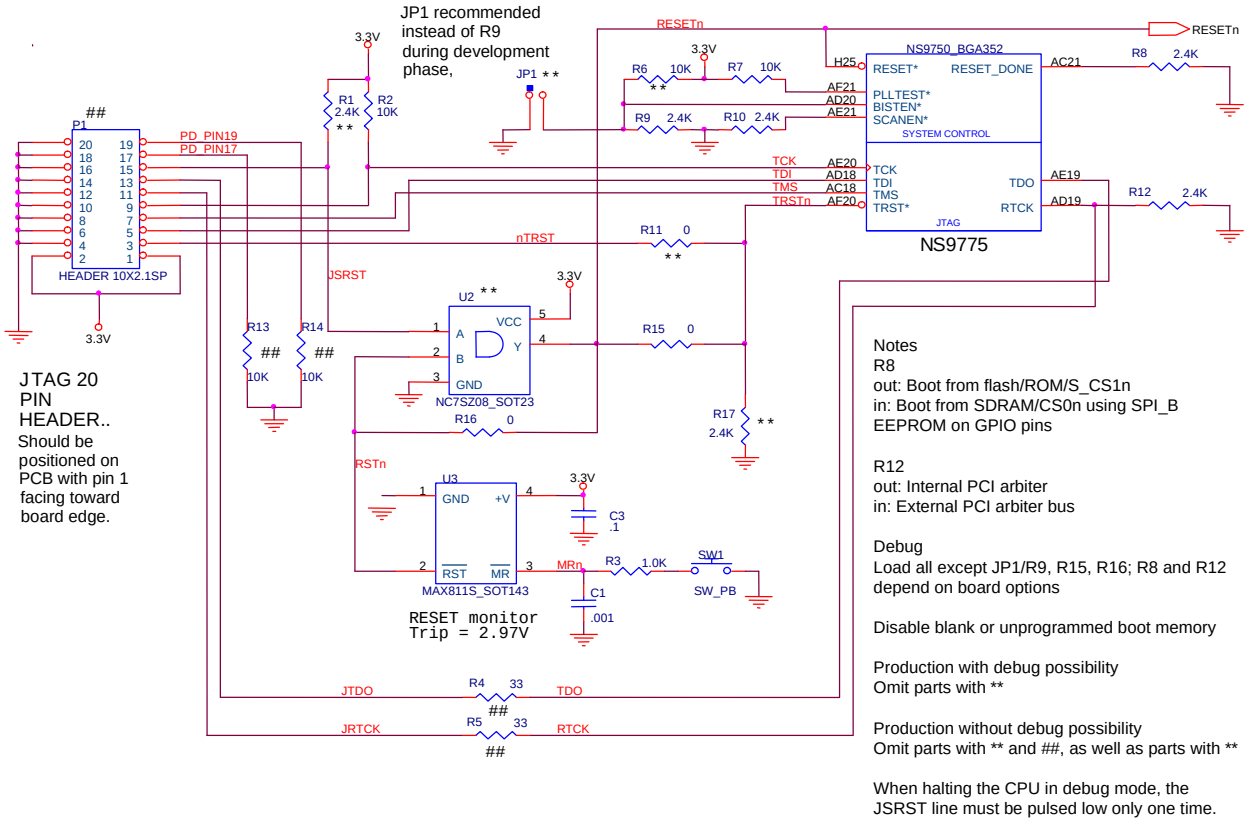


Figure 10: JTAG interface

Reserved

Pin#	Description
AF22	No connect
AD21	No connect
AE22	No connect

Table 16: Reserved pins

Power ground

Pin #	Signal name	Description
J23, L23, K23, U23, T23, V23, D18, D17, AC17, D16, AC16, D11, D10, AC11, AC10, AC9, J4, L4, K4, U4, T4, V4	VDDC	Core power, 1.5V
G23, H23, M23, R23, P23, N23, Y23, W23, D20, AC20, D19, AC19, D14, D13, AC14, AC13, D8, D7, AC8, AC7, G4, H4, M4, R4, P4, N4, Y4, W4	VDDS	I/O power, 3.3V
A26, B25, AE25, AF26, D23, C24, AD24, AC23, D5, D4, C4, E4, AC4, A3, A2, D3, C3, C2, B3, B2, AE2, AD3, A1, C1, B1, AF1	VSS2	Ground

Table 17: Power ground pins

Working with the CPU

CHAPTER 3

The NS9775 core is based on the ARM926EJ-S processor. The ARM926EJ-S processor belongs to the ARM9 family of general-purpose microprocessors. The ARM926EJ-S processor is targeted at multi-tasking applications in which full memory management, high performance, low die size, and low power are important.

About the processor

The ARM926EJ-S processor supports the 32-bit ARM and 16-bit Thumb instructions sets, allowing you to trade off between high performance and high code density. The processor includes features for efficient execution of Java byte codes, providing Java performance similar to JIT but without the associated overhead.

The ARM926EJ-S supports the ARM debug architecture, and includes logic to assist in both hardware and software debug. The processor has a Harvard-cached architecture and provides a complete high-performance processor subsystem, including:

- ARM926EJ-S integer core
- Memory Management Unit (MMU) (see "Memory Management Unit (MMU)," beginning on page 82, for information)
- Separate instruction and data AMBA AHB bus interfaces

Figure 11 shows the main blocks in the ARM926EJ-S processor.

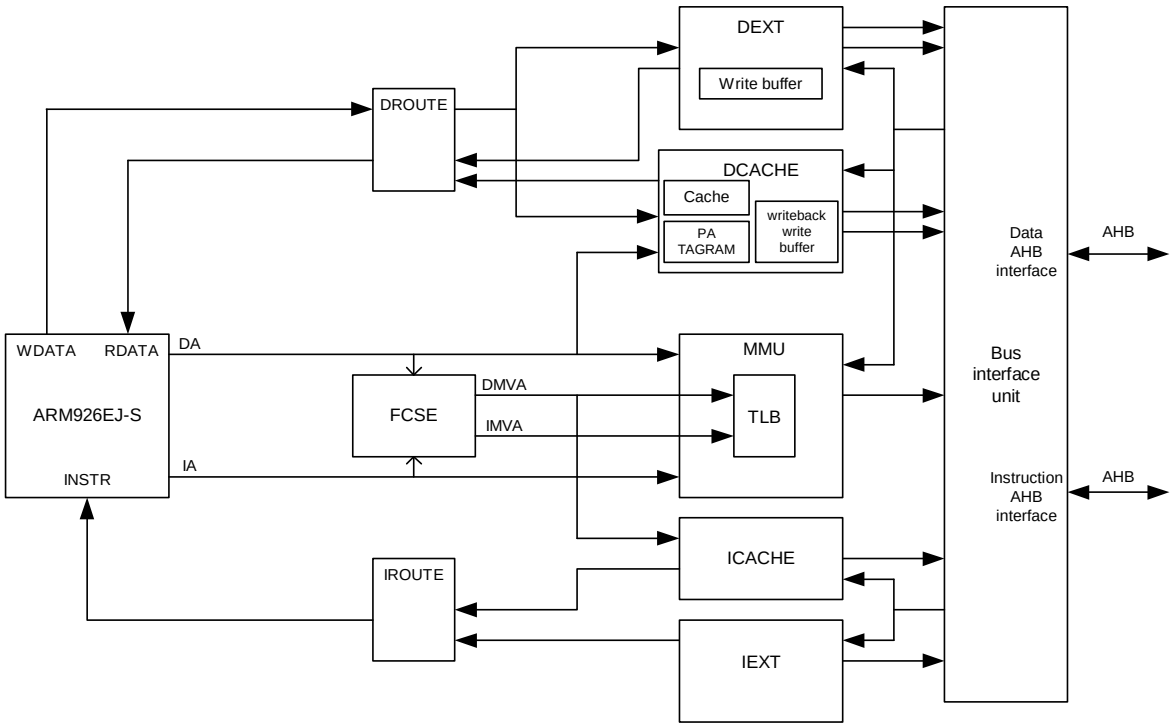


Figure 11: ARM926EJ-S processor block diagram

Instruction sets

The processor executes three instruction sets:

- 32-bit ARM instruction set
- 16-bit Thumb instruction set
- 8-bit Java instruction set

ARM instruction set

The ARM instruction set allows a program to achieve maximum performance with the minimum number of instructions. The majority of instructions are executed in a single cycle.

Thumb instruction set

The Thumb instruction set is simpler than the ARM instruction set, and offers increased code density for code that does not require maximum performance. Code can switch between ARM and Thumb instruction sets on any procedure call.

Java instruction set

In Java state, the processor core executes a majority of Java bytecodes naturally. Bytecodes are decoded in two states, compared to a single decode stage when in ARM/Thumb mode. See "Jazelle (Java)" on page 81 for more information about Java.

System control processor (CP15) registers

The system control processor (CP15) registers configure and control most of the options in the ARM926EJ-S processor. Access the CP15 registers using only the MRC and MCR instructions in a privileged mode; the instructions are provided in the explanation of each applicable register. Using other instructions, or MRC and MCR in unprivileged mode, results in an UNDEFINED instruction exception.

ARM926EJ-S system addresses

The ARM926EJ-S has three distinct types of addresses:

- In the ARM926EJ-S domain: Virtual address (VA)
- In the Cache and MMU domain: Modified virtual address (MVA)
- In the AMBA domain: Physical address (PA)

Example

This is an example of the address manipulation that occurs when the ARM926EJ-S core requests an instruction:

1. The ARM926EJ-S core issues the virtual address of the instruction.
2. The virtual address is translated using the FCSE PID (fast context switch extension process ID) value to the modified virtual address. The instruction cache (ICache) and memory management unit (MMU) find the modified virtual address (see "R13: Process ID register" on page 79).
3. If the protection check carried out by the MMU on the modified virtual address does not abort and the modified virtual address tag is in the ICache, the instruction data is returned to the ARM926EJ-S core.

   If the protection check carried out by the MMU on the modified virtual address does not abort but the cache misses (the MVA tag is not in the cache), the MMU translates the modified virtual address to produce the physical address. This address is given to the AMBA bus interface to perform an external access.

Accessing CP15 registers

Use only MRC and MCR instructions, only in privileged mode, to access CP15 registers. Figure 12 shows the MRC and MCR instruction bit pattern.

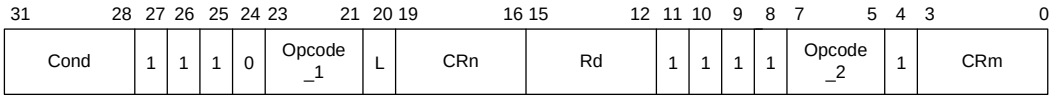


Figure 12: CP15 MRC and MCR bit pattern

The mnemonics for these instructions are:

```
MCR{cond} p15,opcode_1,Rd,CRn,CRm,opcode_2
MRC{cond} p15,opcode_1,Rd,CRn,CRm,opcode_2
```

If you try to read from a write-only register or write to a read-only register, you will have UNPREDICTABLE results. In all instructions that access CP15:

- The opcode_1 field SHOULD BE ZERO, except when the values specified are used to select the operations you want. Using other values results in unpredictable behavior.
- The opcode_2 and CRm fields SHOULD BE ZERO, except when the values specified are used to select the behavior you want. Using other values results in unpredictable behavior.

Terms and abbreviations

Table 18 lists the terms and abbreviations used in the CP15 registers and explanations.

Term	Abbreviation	Description
UNPREDICTABLE	UNP	**For reads:** The data returned when reading from this location is unpredictable, and can have any value. **For writes:** Writing to this location causes unpredictable behavior, or an unpredictable change in device configuration.
UNDEFINED	UND	An instruction that accesses CP15 in the manner indicated takes the `UNDEFINED` instruction exception.
SHOULD BE ZERO	SBZ	When writing to this field, all bits of the field `SHOULD BE ZERO`.
SHOULD BE ONE	SBO	When writing to this location, all bits in this field `SHOULD BE ONE`.
SHOULD BE ZERO or PRESERVED	SBZP	When writing to this location, all bits of this field `SHOULD BE ZERO` or `PRESERVED` by writing the same value that has been read previously from the same field.

Table 18: CP15 terms and abbreviations

Note: In all cases, reading from or writing any data values to any CP15 registers, including those fields specified as `UNPREDICTABLE`, `SHOULD BE ONE`, or `SHOULD BE ZERO`, does not cause any physical damage to the chip.

Register summary

CP15 uses 16 registers.

- Register locations 0, 5, and 13 each provide access to more than one register. The register accessed depends on the value of the `opcode_2` field in the CP15 `MRC/MCR` instructions (see "Accessing CP15 registers" on page 56).
- Register location 9 provides access to more than one register. The register accessed depends on the value of the `CRm` field (see "Accessing CP15 registers" on page 56).

Register	Reads	Writes
0	ID code (based on opcode_2 value)	Unpredictable
0	Cache type (based on opcode_2 value)	Unpredictable
1	Control	Control
2	Translation table base	Translation table base
3	Domain access control	Domain access control
4	Reserved	Reserved
5	Data fault status (based on opcode_2 value)	Data fault status (based on opcode_2 value)
6	Instruction fault status (based on opcode_2 value)	Instruction fault status (based on opcode_2 value)
7	Cache operations	Cache operations
8	Unpredictable	TLB
9	Cache lockdown (based on CRm value)	Cache lockdown
10	TLB lockdown	TLB lockdown
11 and 12	Reserved	Reserved
13	FCSE PID (based on opcode_2 value) FCSE = Fast context switch extension PID = Process identifier	FCSE PID (based on opcode_2 value) FCSE = Fast context switch extension PID = Process identifier
13	Context ID (based on opcode_2 value)	Context ID (based on opcode_2 value)
14	Reserved	Reserved
15	Test configuration	Test configuration

Table 19: CP15 register summary

All CP15 register bits that are defined and contain state are set to 0 by reset, with these exceptions:

- The V bit is set to 0 at reset if the VINITHI signal is low, and set to 1 if the VINITHI signal is high.
- The B bit is set to 0 at reset if the BIGENDINIT signal is low, and set to 1 if the BIGENDINIT signal is high.

R0: ID code and cache type status registers

Register R0 access the ID register, and cache type register. Reading from R0 returns the device ID, and the cache type, depending on the `opcode_2` value:

opcode_2 = 0	ID value
opcode_2 = 1	instruction and data cache type

The `CRm` field `SHOULD BE ZERO` when reading from these registers. Table 20 shows the instructions you can use to read register R0.

Function	Instruction
Read ID code	`MRC p15,0,Rd,c0,c0,{0, 3-7}`
Read cache type	`MRC p15,0,Rd,c0,c0,1`

Table 20: Reading from register R0

Writing to register R0 is `UNPREDICTABLE`.

R0: ID code

R0: ID code is a read-only register that returns the 32-bit device ID code. You can access the ID code register by reading CP15 register R0 with the `opcode_2` field set to any value other than 1 or 2. Note this example:

```
MRC p15, 0, Rd, c0, c0, {0, 3-7}; returns ID
```

Table 21 shows the contents of the ID code register.

Bits	Function	Value
[31:24]	ASCII code of implementer trademark	0x41
[23:20]	Specification revision	0x0
[19:16]	Architecture (ARMv5TEJ)	0x6
[15:4]	Part number	0x926
[3:0]	Layout revision	0x0

Table 21: R0: ID code

R0: Cache type register

R0: Cache type is a read-only register that contains information about the size and architecture of the instruction cache (ICache) and data cache (DCache) enabling operating systems to establish how to perform operations such as cache cleaning and lockdown. See "Cache features" on page 109 for more information about cache.

You can access the cache type register by reading CP15 register R0 with the `opcode_2` field set to 1. Note this example:

```
MRC p15, 0, Rd, c0, c0, 1; returns cache details
```

Figure 13 shows the format of the cache type register. Table 22 describes the fields in the register.

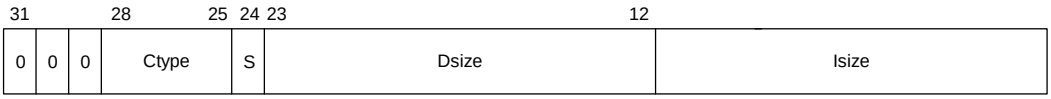


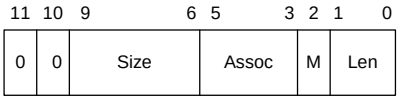
Figure 13: Cache type register format

Field	Description
Ctype	Determines the cache type, and specifies whether the cache supports lockdown and how it is cleaned. Ctype encoding is shown below; all unused values are reserved. Value: 0b1110 Method: Writeback Cache cleaning: Register 7 operations (see "R7: Cache Operations register" on page 68) Cache lockdown: Format C (see "R9: Cache Lockdown register" on page 74)
S bit	Specifies whether the cache is a unified cache (S = 0) or separate ICache and DCache (S = 1). Will always report separate ICache and DCache for NS9775.
Dsize	Specifies the size, line length, and associativity of the DCache.
Isize	Species the size, length and associativity of the ICache.

Table 22: Cache type register field definition

Dsize and Isize fields

The Dsize and Isize fields in the cache type register have the same format, as shown:



The field contains these bits:

Field	Description
Size	Determines the cache size in conjunction with the M bit. ■ The M bit is 0 for DCache and ICache. ■ The size field is bits [21:18] for the DCache and bits [9:6] for the ICache. ■ The minimum size of each cache is 4 KB; the maximum size is 128 KB. ■ Cache size encoding with M = 0: **Size field** — **Cache size** 0b0011 — 4 KB 0b0100 — 8 KB **Note:** The NS9775 always reports 4KB for DCache and 8KB for ICache.
Assoc	Determines the cache associativity in conjunction with the M bit. ■ The M bit is 0 for both DCache and ICache. ■ The assoc field is bits [17:15 for the DCache and bits [5:3] for the ICache. ■ Cache associativity with encoding: **Assoc field** — **Associativity** 0b010 — 4-way Other values — Reserved
M bit	Multiplier bit. Determines the cache size and cache associativity values in conjunction with the size and assoc fields. **Note:** This field must be set to 0 for the ARM926EJ-S processor.
Len	Determines the line length of the cache. ■ The len field is bits [13:12] for the DCache and bits [1:0] for the ICache. ■ Line length encoding: **Len field** — **Cache line length** 10 — 8 words (32 bytes) Other values — Reserved

R1: Control register

Register R1 is the control register for the ARM926EJ-S processor. This register specifies the configuration used to enable and disable the caches and MMU (memory management unit). It is recommended that you access this register using a read-modify-write sequence.

For both reading and writing, the CRm and opcode_2 fields SHOULD BE ZERO. Use these instructions to read and write this register:

```
MRC p15, 0, Rd, c1, c0, 0 ; read control register
MCR p15, Rd, c1, c0, 0 ; write control register
```

All defined control bits are set to zero on reset except the V bit and B bit.

- The V bit is set to zero at reset if the VINITHI signal is low.
- The B bit is set to zero at reset if the BIGENDINIT signal is low, and set to one if the BIGENDINIT signal is high.

Figure 14 shows the Control register format. Table 23 describes the Control register bit functionality.

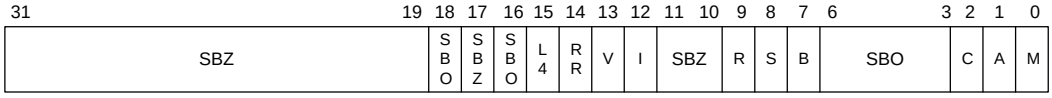


Figure 14: Control register format

Bits	Name	Function
[31:19]	N/A	Reserved: ■ When read, returns an UNPREDICTABLE value. ■ When written, SHOULD BE ZERO, or a value read from bits [31:19] on the same processor. ■ Use a read-modify-write sequence when modifying this register to provide the greatest future compatibility.
[18]	N/A	Reserved, SBO. Read = 1, write =1.
[17]	N/A	Reserved, SBZ. read = 0, write = 0.
[16]	N/A	Reserved, SBO. Read = 1, write = 1.

Table 23: R1: Control register bit definition

Bits	Name	Function
[15]	L4	Determines whether the T is set when load instructions change the PC. 0 Loads to PC set the T bit 1 Loads to PC do not set the T bit
[14]	RR bit	**Replacement strategy for ICache and DCache** 0 Random replacement 1 Round-robin replacement
[13]	V bit	**Location of exception vectors** 0 Normal exception vectors selected; address range = 0x0000 0000 to 0x0000 001C 1 High exception vectors selected; address range = 0xFFFF 0000 to 0xFFFF 001C Set to the value of VINITHI on reset.
[12]	I bit	**ICache enable/disable** 0 ICache disabled 1 ICache enabled
[11:10]	N/A	SHOULD BE ZERO
[9]	R bit	**ROM protection** Modifies the ROM protection system.
[8]	S bit	**System protection** Modifies the MMU protection system. See "Memory Management Unit (MMU)," beginning on page 82.
[7]	B bit	Endianness 0 Little endian operation 1 Big endian operation Set to the value of BIGENDINIT on reset.
[6:3]	N/A	Reserved. SHOULD BE ONE.
[2]	C bit	**DCache enable/disable** 0 Cache disabled 1 Cache enabled
[1]	A bit	**Alignment fault enable/disable** 0 Data address alignment fault checking disabled 1 Data address alignment fault checking enabled

Table 23: R1: Control register bit definition

Bits	Name	Function
[0]	M bit	**MMU enable/disable** 0 Disabled 1 Enabled

Table 23: R1: Control register bit definition

The M, C, I, and RR bits directly affect ICache and DCache behavior, as shown:

Cache	MMU	Behavior
ICache disabled	Enabled or disabled	All instruction fetches are from external memory (AHB).
ICache enabled	Disabled	All instruction fetches are cachable, with no protection checking. All addresses are flat-mapped; that is: VA = MVA = PA.
ICache enabled	Enabled	Instruction fetches are cachable or noncachable, and protection checks are performed. All addresses are remapped from VA to PA, depending on the MMU page table entry; that is, VA translated to MVA, MVA remapped to PA.
DCache disabled	Enabled or disabled	All data accesses are to external memory (AHB).
DCache enabled	Disabled	All data accesses are noncachable nonbufferable. All addresses are flat-mapped; that is, VA = MVA = PA.
DCache enabled	Enabled	All data accesses are cachable or noncachable, and protection checks are performed. All addresses are remapped from VA to PA, depending on the MMU page table entry; that is, VA translated to MVA, MVA remapped to PA.

Table 24: Effects of Control register on caches

If either the DCache or ICache is disabled, the contents of that cache are not accessed. If the cache subsequently is re-enabled, the contents will not have changed. To guarantee that memory coherency is maintained, the DCache must be cleaned of dirty data before it is disabled.

R2: Translation Table Base register

Register R2 is the Translation Table Base register (TTBR), for the base address of the first-level translation table.

- Reading from R2 returns the pointer to the currently active first-level translation table in bits [31:14] and an UNPREDICTABLE value in bits [13:0].
- Writing to R2 updates the pointer to the first-level translation table from the value in bits[31:14] of the written value. Bits [13:0] SHOULD BE ZERO.

Use these instructions to access the Translation Table Base register:

```
MRC p15, 0, Rd, c2, c0, 0 ; read TTBR
MCR p15, 0, Rd, c2, c0, 0 ; write TTBR
```

The CRm and opcode_2 fields SHOULD BE ZERO when writing to R2.

Figure 15 shows the format of the Translation Table Base register.

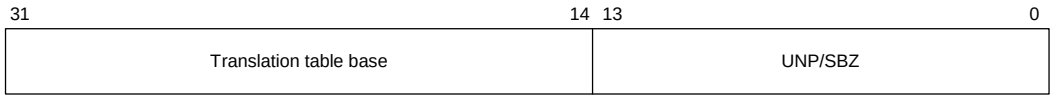


Figure 15: R2: Translation Table Base register

R3: Domain Access Control register

Register R3 is the Domain Access Control register and consists of 16 two-bit fields, as shown in Figure 16.

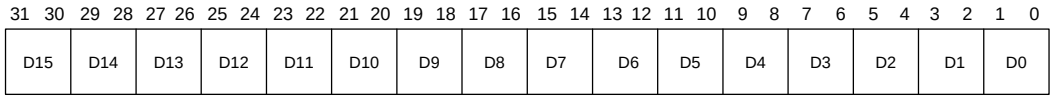


Figure 16: R3: Domain Access Control register

- Reading from R3 returns the value of the Domain Access Control register.
- Writing to R3 writes the value of the Domain Access Control register.

Each two-bit field defines the access permissions for one of the 16 domains (D15–D0):

00 No access: Any access generates a domain fault

01 Client: Accesses are checked against the access permission bits in the section or page descriptor

10 Reserved: Currently behaves like no access mode (00)

11 Manager: Accesses are not checked against the access permission bits, so a permission fault cannot be generated.

Use these instructions to access the Domain Access Control register:

```
MRC p15, 0, Rd, c3, c0, 0 ; read domain access permissions
MCR p15, 0, Rd, c3, c0, 0 ; write domain access permissions
```

R4 register

Accessing (reading or writing) this register causes UNPREDICTABLE behavior.

R5: Fault Status registers

Register R5 accesses the Fault Status registers (FSRs). The Fault Status registers contain the source of the last instruction or data fault. The instruction-side FSR is intended for debug purposes only.

The FSR is updated for alignment faults and for external aborts that occur while the MMU is disabled. The FSR accessed is determined by the opcode_2 value:

opcode_2 = 0	Data Fault Status register (DFSR)
opcode_2 = 1	Instruction Fault Status register (IFSR)

See "Memory Management Unit (MMU)," beginning on page 82, for the fault type encoding.

Access the FSRs using these instructions:

```
MRC p15, 0, Rd, c5, c0, 0 ; read DFSR
MCR p15, 0, Rd, c5, c0, 0 ; write DFSR
MRC p15, 0, Rd, c5, c0, 1 ; read IFSR
MCR p15, 0, Rd, c5, c0, 1 ; write IFSR
```

Figure 17 shows the format of the Fault Status registers. Table 25 describes the Fault Status register bits.

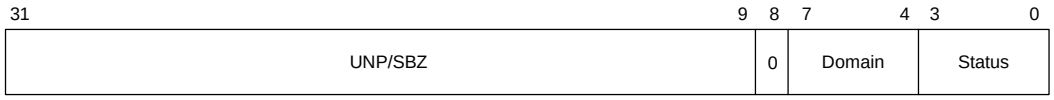


Figure 17: Fault Status registers format

Bits	Description
[31:9]	UNPREDICTABLE/SHOULD BE ZERO
[8]	Always reads as zero. Writes are ignored.
[7:4]	Specifies which of the 16 domains (D15–D0) was being accessed when a data fault occurred.
[3:0]	Type of fault generated. (See "Memory Management Unit (MMU)," beginning on page 82.)

Table 25: Fault Status register bit description

Table 26 shows the encodings used for the status field in the Fault Status register, and indicates whether the domain field contains valid information. See "MMU faults and CPU aborts" on page 99 for information about MMU aborts in Fault Address and Fault Status registers.

Priority	Source	Size	Status	Domain
Highest	Alignment	N/A	0b00x1	Invalid
	External abort on translation	First level Second level	0b1100 0b1110	Invalid Valid
	Translation	Section page	0b0101 0b0111	Invalid Valid
	Domain	Section page	0b1001 0b1011	Valid Valid
	Permission	Section page	0b1101 0b1111	Valid Valid

Table 26: Fault Status register status field encoding

Priority	Source	Size	Status	Domain
Lowest	External abort	Section page	0b1000 0b1010	Valid Valid

Table 26: Fault Status register status field encoding

R6: Fault Address register

Register R6 accesses the Fault Address register (FAR). The Fault Address register contains the modified virtual address of the access attempted when a data abort occurred. This register is updated only for data aborts, not for prefetch aborts; it is updated also for alignment faults and external aborts that occur while the MMU is disabled.

Use these instructions to access the Fault Address register:

```
MRC p15, 0, Rd, c6, c0, 0 ; read FAR
MCR p15, 0, Rd, c6, c0, 0 ; write FAR
```

Writing R6 sets the Fault Address register to the value of the data written. This is useful for debugging, to restore the value of a Fault Address register to a previous state.

The CRm and opcode_2 fields SHOULD BE ZERO when reading or writing R6.

R7: Cache Operations register

Register R7 controls the caches and write buffer. The function of each cache operation is selected by the opcode_2 and CRm fields in the MCR instruction that writes to CP15 R7. Writing other opcode_2 or CRm values is UNPREDICTABLE.

Reading from R7 is UNPREDICTABLE, with the exception of the two test and clean operations (see Table 28, “R7: Cache operations,” on page 70 and "Test and clean operations" on page 72).

Use this instruction to write to the Cache Operations register:

```
MCR p15, opcode_1, Rd, CRn, CRm, opcode_2
```

Table 27 describes the cache functions provided by register R7. Table 28 lists the cache operation functions and associated data and instruction formats for R7.

Function	Description
Invalidate cache	Invalidates all cache data, including any dirty data.
Invalidate single entry using either index or modified virtual address	Invalidates a single cache line, discarding any dirty data.
Clean single data entry using either index or modified virtual address	Writes the specified DCache line to main memory if the line is marked valid and dirty. The line is marked as not dirty, and the valid bit is unchanged.
Clean and invalidate single data entry using wither index or modified virtual address.	Writes the specified DCache line to main memory if the line is marked valid and dirty. The line is marked not valid.
Test and clean DCache	Tests a number of cache lines, and cleans one of them if any are dirty. Returns the overall dirty state of the cache in bit 30. (See "Test and clean operations" on page 72).
Test, clean, and invalidate DCache	Tests a number of cache lines, and cleans one of them if any are dirty. When the entire cache has been tested and cleaned, it is invalidated. (See "Test and clean operations" on page 72).
Prefetch ICache line	Performs an ICache lookup of the specified modified virtual address. If the cache misses and the region is cachable, a linefill is performed.
Drain write buffer	Acts as an explicit memory barrier. This instruction drains the contents of the write buffers of all memory stores occurring in program order before the instruction is completed. No instructions occurring in program order after this instruction are executed until the instruction completes. Use this instruction when timing of specific stores to the level two memory system has to be controlled (for example, when a store to an interrupt acknowledge location has to complete before interrupts are enabled).

Table 27: Cache Operations register function descriptions

Function	Description
Wait for interrupt	Drains the contents of the write buffers, puts the processor into low-power state, and stops the processor from executing further instructions until an interrupt (or debug request) occurs. When an interrupt does occur, the `MCR` instruction completes, and the IRQ or FIRQ handler is entered as normal. The return link in `R14_irq` or `R14_fiq` contains the address of the `MCR` instruction plus eight, so the typical instruction used for interrupt return `(SUBS PC,R14,#4)` returns to the instruction following the `MCR`.

Table 27: Cache Operations register function descriptions

Function/operation	Data format	Instruction
Invalidate ICache and DCache	SBZ	`MCR p15, 0, Rd, c7, c7, 0`
Invalidate ICache	SBZ	`MCR p15, 0, Rd, c7, c5, 0`
Invalidate ICache single entry (MVA)	MVA	`MCR p15, 0, Rd, c7, c5, 1`
Invalidate ICache single entry (set/way)	Set/Way	`MCR p15, 0, Rd, c7, c5, 2`
Prefetch ICache line (MVA)	MVA	`MCR p15, 0, Rd, c7, c13, 1`
Invalidate DCache	SBZ	`MCR p15, 0, Rd, c7, c6, 0`
Invalidate DCache single entry (MVA)	MVA	`MCR p15, 0, Rd, c7, c6, 1`
Invalidate DCache single entry (set/way)	Set/Way	`MCR p15, 0, Rd, c7, c6, 2`
Clean DCache single entry (MVA)	MVA	`MCR p15, 0, Rd, c7, c10, 1`
Clean DCache single entry (set/way)	Set/Way	`MCR p15, 0, Rd, c7, C10, 2`
Test and clean DCache	n/a	`MRC p15, 0, Rd, c7, c10, 3`
Clean and invalidate DCache entry (MVA)	MVA	`MCR p15, 0, Rd, c7, c14, 1`
Clean and invalidate DCache entry (set/way)	Set/Way	`MCR p15, 0, Rd, c7, c14, 2`
Test, clean, and invalidate DCache	n/a	`MRC p15, 0, Rd, c7, c14, 3`

Table 28: R7: Cache operations

Function/operation	Data format	Instruction
Drain write buffer	SBZ	`MCR p15, 0, Rd, c7, c10, 4`
Wait for interrupt	SBZ	`MCR p15, 0, Rd, c7, c0, 4`

Table 28: R7: Cache operations

Figure 18 shows the modified virtual address format for `Rd` for the CP15 R7 `MCR` operations.

- The tag, set, and word fields define the MVA.
- For all cache operations, the word field `SHOULD BE ZERO`.

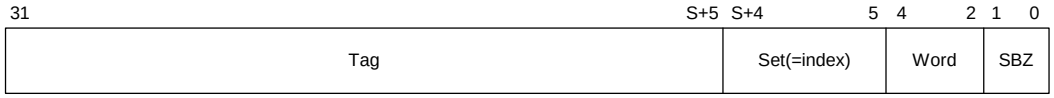


Figure 18: R7: MVA format

Figure 19 shows the Set/Way format for `Rd` for the CP15 R7 `MCR` operations.

- A and S are the base-two logarithms of the associativity and the number of sets.
- The set, way, and word files define the format.
- For all of the cache operations, word `SHOULD BE ZERO`.

For example, a 16 KB cache, 4-way set associative, 8-word line results in the following:

- A = $\log_2$ associativity = $\log_2 4 = 2$
- S = $\log_2$ NSETS where

  NSETS = cache size in bytes/associativity/line length in bytes:

  NSETS = 16384/4/32 = 128

  Result: S = $\log_2 128 = 7$

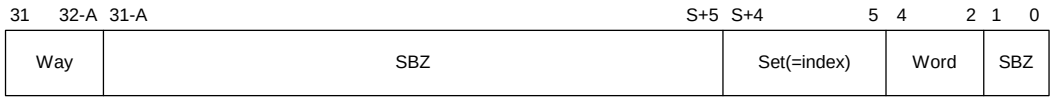


Figure 19: R7: Set/Way format

Test and clean operations

Test and clean DCache instruction

The test and clean DCache instruction provides an efficient way to clean the entire DCache, using a simple loop. The test and clean DCache instruction tests a number of lines in the DCache to determine whether any of them are dirty. If any dirty lines are found, one of those lines is cleaned. The test and clean DCache instruction also returns the status of the entire DCache in bit 30.

Note: The test and clean DCache instruction `MRC p15, 0, r15, c7, c10, 3` is a special encoding that uses `r15` as a destination operand. The PC is not changed by using this instruction, however. This `MRC` instruction also sets the condition code flags.

If the cache contains any dirty lines, bit 30 is set to 0. If the cache contains no dirty lines, bit 30 is set to 1. Use the following loop to clean the entire cache:

```
tc_loop:    MRC p15, 0, r15, c7, c10, 3 ; test and clean
            BNE tc_loop
```

Test, clean, and invalidate DCache instruction

The test, clean, and invalidate DCache instruction is the same as the test and clean DCache instruction except that when the entire cache has been cleaned, it is invalidated. Use the following loop to test, clean, and invalidate the entire DCache:

```
tci_loop:   MRC p15, 0, r15, c7, c14, 3 ; test clean and invalidate
            BNE tci_loop
```

R8:TLB Operations register

Register R8 is a write-only register that controls the translation lookaside buffer (TLB). There is a single TLB used to hold entries for both data and instructions. The TLB is divided into two parts:

- Set-associative
- Fully-associative

The *fully-associative* part (also referred to as the *lockdown* part of the TLB) stores entries to be locked down. Entries held in the lockdown part of the register are preserved during an invalidate-TLB operation. Entries can be removed from the lockdown TLB using an invalidate TLB single entry operation.

There are six TLB operations; the function to be performed is selected by the `opcode_2` and `CRm` fields in the `MCR` instruction used to write register R8. Writing other `opcode_2` or `CRm` values is `UNPREDICTABLE`. Reading from this register is `UNPREDICTABLE`.

Use the instruction shown in Table 29 to perform TLB operations.

Operation	Data	Instruction
Invalidate set-associative TLB	SBZ	`MCR p15, 0, Rd, c8, c7, 0`
Invalidate single entry	SBZ	`MCR p15, 0, Rd, c8, c7. 1`
Invalidate set-associative TLB	SBZ	`MCR p15, 0, Rd, c8, c5, 0`
Invalidate single entry	MVA	`MCR p15, 0, Rd, c8, c5, 1`
Invalidate set-associative TLB	SBZ	`MCR p15, 0, Rd, c8, c6, 0`
Invalidate single entry	MVA	`MCR p15, 0, Rd, c8, c6, 1`

Table 29: R8: Translation Lookaside Buffer operations

- The *invalidate TLB operations* invalidate all the unpreserved entries in the TLB.
- The *invalidate TLB single entry operations* invalidate any TLB entry corresponding to the modified virtual address given in `Rd`, regardless of its preserved state. See "R10: TLB Lockdown register," beginning on page 77, for an explanation of how to preserve TLB entries.

Figure 20 shows the modified virtual address format used for invalid TLB single entry operations.

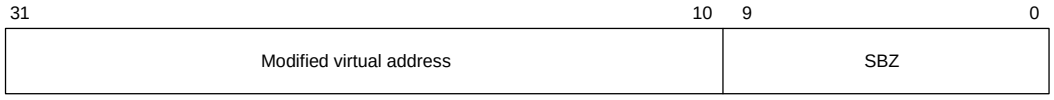


Figure 20: R8: TLB Operations, MVA format

Note: If either small or large pages are used, and these pages contain subpage access permissions that are different, you must use four invalidate TLB single entry operations, with the MVA set to each subpage, to invalidate all information related to that page held in a TLB.

R9: Cache Lockdown register

Register R9 access the cache lockdown registers. Access this register using `CRm = 0`.

The Cache Lockdown register uses a cache-way-based locking scheme (format C) that allows you to control each cache way independently.

These registers allow you to control which cache-ways of the four-way cache are used for the allocation on a linefill. When the registers are defined, subsequent linefills are placed only in the specified target cache way. This gives you some control over the cache pollution cause by particular applications, and provides a traditional lockdown operation for locking critical code into the cache.

A locking bit for each cache way determines whether the normal cache allocation is allowed to access that cache way (see Table 31, “Cache Lockdown register L bits,” on page 75). A maximum of three cache ways of the four-way associative cache can be locked, ensuring that normal cache line replacement is performed.

Note: If no cache ways have the L bit set to 0, cache way 3 is used for all linefills.

The first four bits of this register determine the L bit for the associated cache way. The opcode_2 field of the MRC or MCR instruction determines whether the instruction or data lockdown register is accessed:

opcode_2 = 0	Selects the DCache Lockdown register, or the Unified Cache Lockdown register if a unified cache is implemented. The ARM926EJ-S processor has separate DCache and ICache.
opcode_2 = 1	Selects the ICache Lockdown register.

Use the instructions shown in Table 30 to access the CacheLockdown register.

Function	Data	Instruction
Read DCache Lockdown register	L bits	`MRC p15, 0, Rd, c9, c0, 0`
Write DCache Lockdown register	L bits	`MCR p15, 0, Rd, c9, c0, 0`
Read ICache Lockdown register	L bits	`MRC p15, 0, Rd, c9, c0, 1`
Write ICache Lockdown register	L bits	`MCR p15, 0, Rd, c9, c0, 1`

Table 30: Cache Lockdown register instructions

You must modify the Cache Lockdown register using a modify-read-write sequence; for example:

```
MRC p15, 0, Rn, c9, c0, 1 ;
ORR Rn, Rn, 0x01 ;
MCR p15, 0, Rn, c9, c0, 1 ;
```

This sequence sets the L bit to 1 for way 0 of the ICache. Figure 21 shows the format for the Cache Lockdown register.

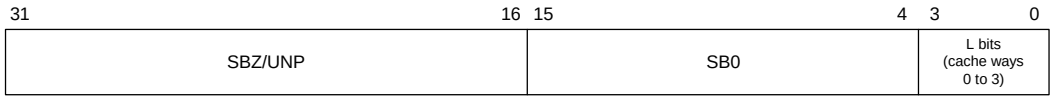


Figure 21: R9: Cache Lockdown register format

Table 31 shows the format of the Cache Lockdown register L bits. All cache ways are available for allocation from reset.

Bits	4-way associative	Notes
[31:16]	UNP/SBZ	Reserved
[15:4]	0xFFF	SBO
[3]	L bit for way 3	Bits [3:0] are the L bits for each cache way: 0 Allocation to the cache way is determined by the standard replacement algorithm (reset state) 1 No allocation is performed to this way
[2]	L bit for way 2	
[1]	L bit for way 1	
[0]	L bit for way 0	

Table 31: Cache Lockdown register L bits

Use one of these procedures to lockdown and unlock cache:

- Specific loading of addresses into a cache way
- Cache unlock procedure

Specific loading of addresses into a cache-way

The procedure to lock down code and data into way *i* of cache, with *N* ways, using format C, makes it impossible to allocate to any cache way other than the target cache way:

1. Ensure that no processor exceptions can occur during the execution of this procedure; for example, disable interrupts. If this is not possible, all code and data used by any exception handlers must be treated as code and data as in Steps 2 and 3.
2. If an ICache way is being locked down, be sure that all the code executed by the lockdown procedure is in an uncachable area of memory or in an already locked cache way.
3. If a DCache way is being locked down, be sure that all data used by the lockdown procedure is in an uncachable area of memory or is in an already locked cache way.
4. Ensure that the data/instructions that are to be locked down are in a cachable area of memory.
5. Be sure that the data/instructions that are to be locked down are not already in the cache. Use the Cache Operations register (R7) clean and/or invalidate functions to ensure this.
6. Write these settings to the Cache Lockdown register (R9), to enable allocation to the target cache way:

   ```
   CRm = 0
   Set L == 0 for bit i
   Set L == 1 for all other bits
   ```

7. For each of the cache lines to be locked down in cache way *i*:
   - If a DCache is being locked down, use an `LDR` instruction to load a word from the memory cache line to ensure that the memory cache line is loaded into the cache.
   - If an ICache is being locked down, use the Cache Operations register (R7) `MCR` prefetch ICache line `(<CRm>==c13, <opcode2>==1)` to fetch the memory cache line into the cache.
8. Write `<CRm>==0` to Cache Lockdown register (R9), setting `L==1` for bit *i* and restoring all other bits to the values they had before the lockdown routine was started.

Cache unlock procedure

To unlock the locked down portion of the cache, write to Cache Lockdown register (R9) setting `L==0` for the appropriate bit. The following sequence, for example, sets the L bit to 0 for way 0 of the ICache, unlocking way 0:

```
MRC p15, 0, Rn, c9, c0, 1;
BIC Rn, Rn, 0x01 ;
MCR p15, 0, Rn, c9, c0, 1;
```

R10: TLB Lockdown register

The TLB Lockdown register controls where hardware page table walks place the TLB entry — in the set associative region or the lockdown region of the TLB. If the TLB entry is put in the lockdown region, the register indicates which entry is written. The TLB lockdown region contains eight entries (see the discussion of the TLB structure in "TLB structure," beginning on page 108, for more information).

Figure 22 shows the TLB lockdown format.

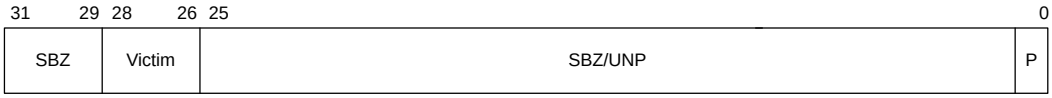


Figure 22: TLB Lockdown register format

When writing the TLB Lockdown register, the value in the P bit (D0) determines in which region the TLB entry is placed:

P = 0	Subsequent hardware page table walks place the TLNB entry in the set associative region of the TLB.
P = 1	Subsequent hardware page table walks place the TLB entry in the lockdown region at the entry specified by the victim, in the range 0–7.

TLB entries in the lockdown region are preserved so invalidate-TLB operations only invalidate the unpreserved entries in the TLB; that is, those entries in the set-associative region. Invalidate-TLB single entry operations invalidate any TLB entry corresponding to the modified virtual address given in `Rd`, regardless of the entry's preserved state; that is, whether they are in lockdown or set-associative TLB regions.

See "R8:TLB Operations register" on page 72 for a description of the TLB-invalidate operations.

Use these instructions to program the TLB Lockdown register:

Function	Instruction
Read data TLB lockdown victim	`MRC p15, 0, Rd, c10, c0, 0`
Write data TLB lockdown victim	`MCR p15, 0, Rd, c10, c0, 0`

The victim automatically increments after any table walk that results in an entry being written into the lockdown part of the TLB.

Note: It is not possible for a lockdown entry to map entirely either small or large pages, unless all subpage access permissions are the same. Entries can still be written into the lockdown region, but the address range that is mapped covers only the subpage corresponding to the address that was used to perform the page table walk.

Sample code sequence

This example shows the code sequence that locks down an entry to the current victim.

```
ADR r1,LockAddr             ;   set R1 to the value of the address to be locked
                                down
MCR p15,0,r1,c8,c7,1        ;   invalidate TLB single entry to ensure that
                                LockAddr is not already in the TLB
MRC p15,0,r0,c10,c0,0       ;   read the lockdown register
ORR r0,r0,#1                ;   set the preserve bit
MCR p15,0,r0,c10,c0,0       ;   write to the lockdown register
LDR r1,[r1]                 ;   TLB will miss, and entry will be loaded
MRC p15,0,r0,c10,c0,0       ;   read the lockdown register (victim will have
                            ;   incremented
BIC r0,r0,#1                ;   clear preserve bit
MCR p15,0,r0,c10,c0,0       ;   write to the lockdown register
```

R11 and R12 registers

Accessing (reading or writing) these registers causes `UNPREDICTABLE` behavior.

R13: Process ID register

The Process ID register accesses the process identifier registers. The register accessed depends on the value on the `opcode_2` field:

opcode_2 = 0	Selects the *Fast Context Switch Extension* (FCSE) *Process Identifier* (PID) register.
opcode_2 = 1	Selects the context ID register.

Use the Process ID register to determine the process that is currently running. The process identifier is set to 0 at reset.

FCSE PID register

Addresses issued by the ARM926EJ-S core, in the range 0 to 32 MB, are translated according to the value contained in the FCSE PID register. Address A becomes `A + (FCSE PID x 32 MB)`; it is this modified address that the MMU and caches see. Addresses above 32 MB are not modified. The FCSE PID is a 7-bit field, which allows 128 x 32 MB processes to be mapped.

If the FCSE PID is 0, there is a flat mapping between the virtual addresses output by the ARM926EJ-S core and the modified virtual addresses used by the caches and MMU. The FCSE PID is set to 0 at system reset.

If the MMU is disabled, there is no FCSE address translation.

FCSE translation is not applied for addresses used for entry-based cache or TLB maintenance operations. For these operations, `VA=MVA`.

Use these instructions to access the FCSE PID register:

Function	Data	ARM instruction
Read FCSE PID	FCSE PID	`MRC p15,0,Rd,c13,c0,0`
Write FCSE PID	FCSE PID	`MCR p15,0,Rd,c13,c0,0`

Figure 23 shows the format of the FCSE PID register.

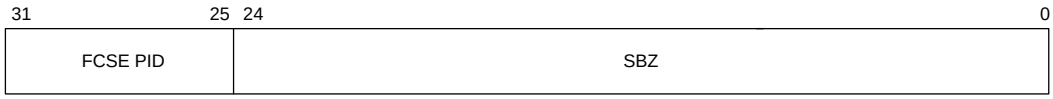


Figure 23: Process ID register format

Performing a fast context switch

You can perform a fast context switch by writing to the Process ID register (R13) with `opcode_2` set to 0. The contents of the caches and the TLB do not have to be flushed after a fast context switch because they still hold address tags. The two instructions after the FCSE PID has been written have been fetched with the old FCSE PID, as shown in this code example:

```
{FCSE PID = 0}
    MOV r0, #1:SHL:25       ;Fetched with FCSE PID = 0
    MCR p15,0,r0,c13,c0,0   ;Fetched with FCSE PID = 0
    A1                      ;Fetched with FCSE PID = 0
    A2                      ;Fetched with FCSE PID = 0
    A3                      ;Fetched with FCSE PID = 1
```

A1, A2, and A3 are the three instructions following the fast context switch.

Context ID register

The Context ID register provides a mechanism that allows real-time trace tools to identify the currently executing process in multi-tasking environments.

Use these instructions to access the Context ID register:

Function	Data	ARM instruction
Read context ID	Context ID	`MRC p15,0,Rd,c13,c0,1`
Write context ID	Context ID	`MCR p15,0,Rd,c13,c0,1`

Figure 24 shows the format of the Context ID register (Rd) transferred during this operation.

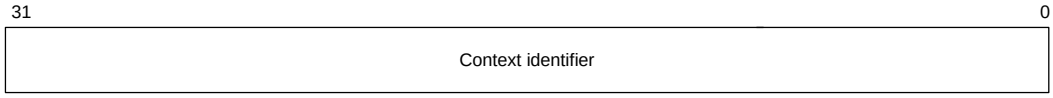


Figure 24: Context ID register format

R14 register

Accessing (reading or writing) this register is reserved.

R15: Test and debug register

Register R15 to provides device-specific test and debug operations in ARM926EJ-S processors. Use of this register currently is reserved.

Jazelle (Java)

The ARM926EJ-S processor has ARM's embedded Jazelle Java acceleration hardware in the core. Java offers rapid application development to software engineers.

The ARM926EJ-S processor core executes an extended ARMv5TE instruction set, which includes support for Java byte code execution (ARMv5TEJ). An ARM optimized *Java Virtual Machine (JVM)* software layer has been written to work with the Jazelle hardware. The Java byte code acceleration is accomplished by the following:

- Hardware, which directly executes 80% of simple Java byte codes.
- Software emulation within the ARM-optimized JVM, which addresses the remaining 20% of the Java byte codes.

DSP

The ARM926EJ-S processor core provides enhanced DSP capability. Multiply instructions are processed using a single cycle 32x16 implementation. There are 32x32, 32x16, and 16x16 multiply instructions, or *Multiply Accumulate (MAC)*, and the pipeline allows one multiply to start each cycle. Saturating arithmetic improves efficiency by automatically selecting saturating behavior during execution, and is used to set limits on signal processing calculations to minimize the effect of noise or signal errors. All of these instructions are beneficial for algorithms that implement the following:

- GSM protocols
- FFT
- State space servo control

Memory Management Unit (MMU)

The MMU provides virtual memory features required by systems operating on platforms such as WindowsCE or Linux. A single set of two-level page tables stored in main memory control the address translation, permission checks, and memory region attributes for both data and instruction accesses. The MMU uses a single, unified *Translation Lookaside Buffer (TLB)* to cache the information held in the page tables. TLB entries can be locked down to ensure that a memory access to a given region never incurs the penalty of a page table walk.

MMU Features

- Standard ARM926EJ-S architecture MMU mapping sizes, domains, and access protection scheme.
- Mapping sizes, as follows:
  - 1 MB for sections
  - 64 KB for large pages
  - 4 KB for small pages

  - 1 KB for tiny pages
- Access permissions for large pages and small pages can be specified separately for each quarter of the page (subpage permissions).
- Hardware page table walks.
- Invalidate entire TLB using R8: TLB Operations register (see "R8:TLB Operations register" on page 72).
- Invalidate TLB entry selected by MVA, using R8: TLB Operations register (see "R8:TLB Operations register" on page 72).
- Lockdown of TLB entries using R10: TLB Lockdown register (see "R10: TLB Lockdown register" on page 77).

Access permissions and domains

For large and small pages, access permissions are defined for each subpage (1 KB for small pages, 16 KB for large pages). Sections and tiny pages have a single set of access permissions.

All regions of memory have an associated domain. A domain is the primary access control mechanism for a region of memory. It defines the conditions necessary for an access to proceed. The domain determines whether:

- Access permissions are used to qualify the access.
- The access is unconditionally allowed to proceed.
- The access is unconditionally aborted.

In the latter two cases, the access permission attributes are ignored.

There are 16 domains, which are configured using R3: Domain Access Control register (see "R3: Domain Access Control register" on page 65).

Translated entries

The TLB caches translated entries. During CPU memory accesses, the TLB provides the protection information to the access control logic.

When the TLB contains a translated entry for the modified virtual address (MVA), the access control logic determines whether:

- Access is permitted and an off-chip access is required — the MMU outputs the appropriate physical address corresponding to the MVA.

- Access is permitted and an off-chip access is not required — the cache services the access.
- Access is not permitted — the MMU signals the CPU core to abort.

If the TLB misses (it does not contain an entry for the MVA), the translation table walk hardware is invoked to retrieve the translation information from a translation table in physical memory. When retrieved, the translation information is written into the TLB, possible overwriting an existing value.

At reset, the MMU is turned off, no address mapping occurs, and all regions are marked as noncachable and nonbufferable.

MMU program accessible registers

Table 32 shows the CP15 registers that are used in conjunction with page table descriptors stored in memory to determine MMU operation.

Register	Bits	Description
R1: Control register	M, A, S, R	Contains bits to enable the MMU (M bit), enable data address alignment checks (A bit), and to control the access protection scheme (S bit and R bit).
R2: Translation Table Base register	[31:14]	Holds the physical address of the base of the translation table maintained in main memory. This base address must be on a 16 KB boundary.
R3: Domain Access Control register	[31:0]	Comprises 16 two-bit fields. Each field defines the access control attributes for one of 16 domains (D15 to D00).
R5: Fault Status registers, IFSR and DFSR	[7:0]	Indicates the cause of a data or prefetch abort, and the domain number of the aborted access when an abort occurs. Bits [7:4] specify which of the 16 domains (D15 to D00) was being accessed when a fault occurred. Bits [3:0] indicate the type of access being attempted. The value of all other bits is UNPREDICTABLE. The encoding of these bits is shown in Table 33, “Priority encoding of fault status,” on page 89).

Table 32: MMU program-accessible CP15 registers

Register	Bits	Description
R6: Fault Address register	[31:0]	Holds the MVA associated with the access that caused the data abort. See Table 33, "Priority encoding of fault status," on page 89 for details of the address stored for each type of fault.
R8: TLB Operations register	[31:0]	Performs TLB maintenance operations. These are either invalidating all the (unpreserved) entries in the TLB, or invalidating a specific entry.
R10: TLB Lockdown register	[28:26] and 0	Enables specific page table entries to be locked into the TLB. Locking entries in the TLB guarantees that accesses to the locked page or section can proceed without incurring the time penalty of a TLB miss. This enables the execution latency for time-critical pieces of code, such as interrupt handlers, to be minimized.

Table 32: MMU program-accessible CP15 registers

All CP15 MMU registers, except R8: TLB Operations, contain state that can be read using MRC instructions, and can be written using MCR instructions. Registers R5 (Fault Status) and R6 (Fault Address) are also written by the MMU during an abort.

Writing to R8: TLB Operations causes the MMU to perform a TLB operation, to manipulate TLB entries. This register is write-only.

Address translation

The virtual address (VA) generated by the CPU core is converted to a modified virtual address (MVA) by the FCSE (fast context switch extension) using the value held in CP15 R13: Process ID register. The MMU translates MVAs into physical addresses to access external memory, and also performs access permission checking.

The MMU table-walking hardware adds entries to the TLB. The translation information that comprises both the address translation data and the access permission data resides in a translation table located in physical memory. The MMU provides the logic for automatically traversing this translation table and loading entries into the TLB.

The number of stages in the hardware table walking and permission checking process is one or two. depending on whether the address is marked as a section-mapped access or a page-mapped access.

There are three sizes of page-mapped accesses and one size of section-mapped access. Page-mapped accesses are for large pages, small pages, and tiny pages.

The translation process always begins in the same way — with a level-one fetch. A section-mapped access requires only a level-one fetch, but a page-mapped access requires an additional level-two fetch.

Translation table base

The hardware translation process is initiated when the TLB does not contain a translation for the requested MVA. R2: Translation Table Base (TTB) register points to the base address of a table in physical memory that contains section or page descriptors, or both. The 14 low-order bits [13:0] of the TTB register are UNPREDICTABLE on a read, and the table must reside on a 16 KB boundary.

Figure 25 shows the format of the TTB register.

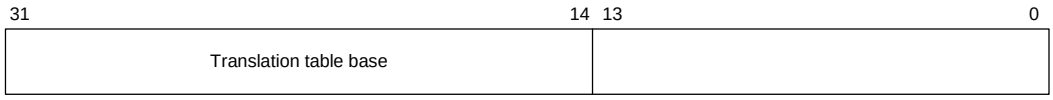


Figure 25: R2: Translation Table base register

The translation table has up to 4096 x 32-bit entries, each describing 1 MB of virtual memory. This allows up to 4 GB of virtual memory to be addressed.

Figure 26 shows the table walk process.

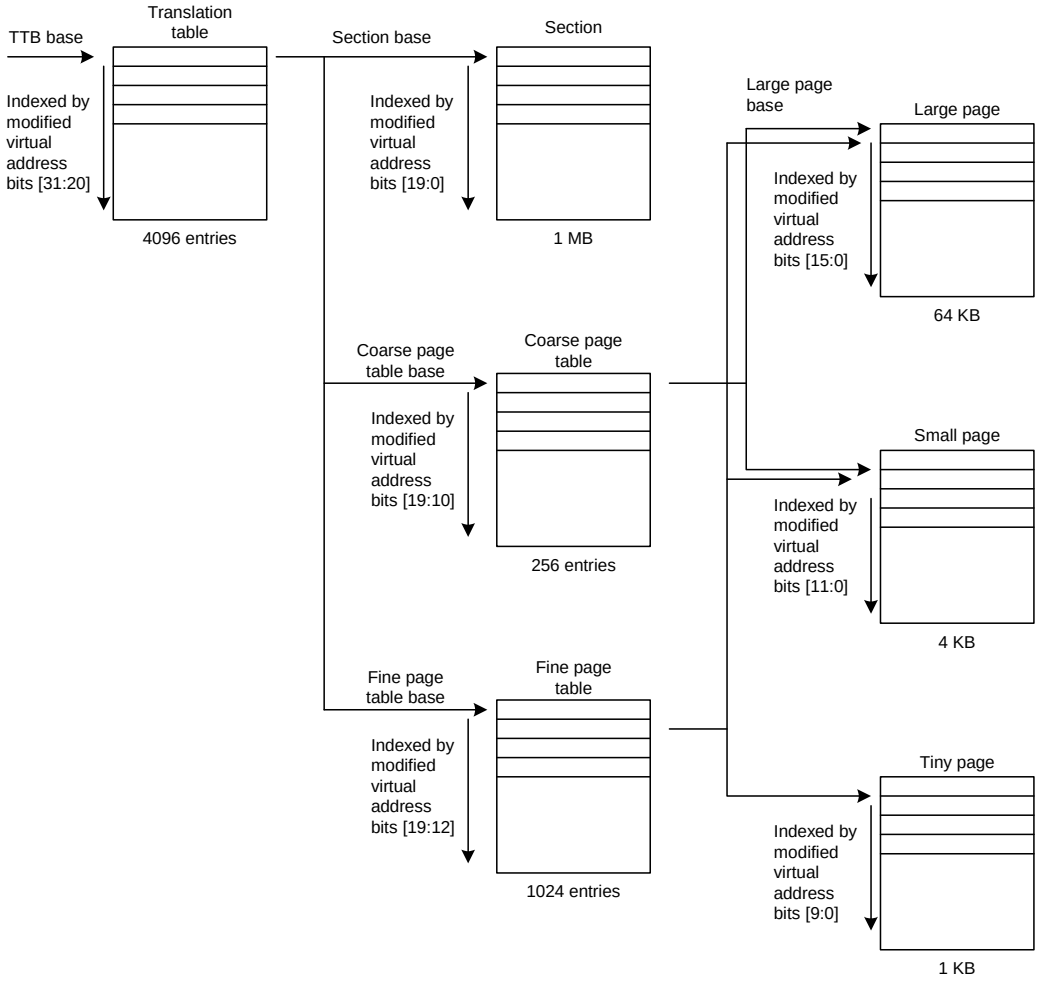


Figure 26: Translating page tables

First-level fetch

Bits [31:14] of the TTB register are concatenated with bits [31:20] of the MVA to produce a 30-bit address.

Figure 27 shows the concatenation and address:

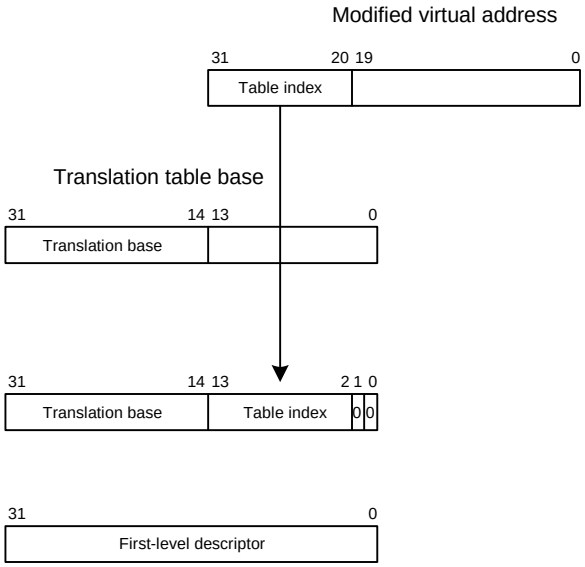


Figure 27: Accessing translation table first-level descriptors

This address selects a 4-byte translation table entry. This is a first-level descriptor for either a section or a page.

First-level descriptor

The first-level descriptor returned is a section description, a coarse page table descriptor, a fine page table descriptor, or is invalid. Figure 28 shows the format of a first-level descriptor.

A section descriptor provides the base address of a 1 MB block of memory.

The page table descriptors provide the base address of a page table that contains second-level descriptors. There are two page-table sizes:

- **Coarse page tables,** which have 256 entries and split the 1 MB that the table describes into 4 KB blocks.

- **Fine page tables,** which have 1024 entries and split the 1 MB that the table describes into 1 KB blocks.

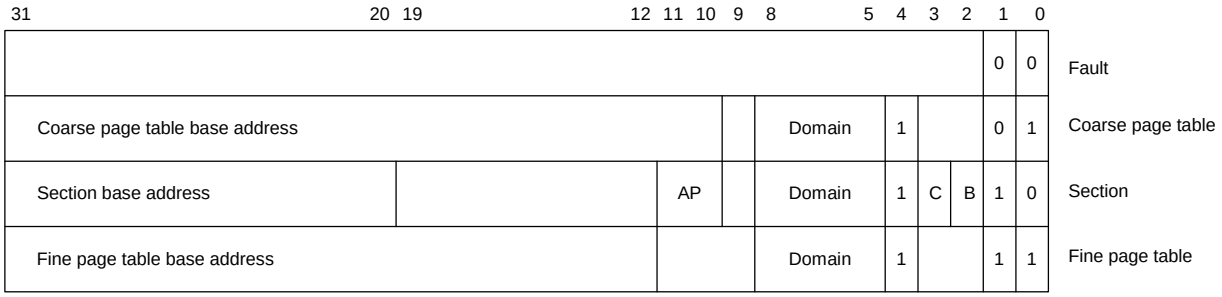


Figure 28: First-level descriptor

Table 33 shows first-level descriptor bit assignments.

Bits			
Section	**Coarse**	**Fine**	**Description**
[31:20]	[31:10]	[31:12]	Forms the corresponding bits of the physical address.
[19:12]	----	---	SHOULD BE ZERO
[11:10]	---	---	Access permission bits. See "Access permissions and domains" on page 83 and "Fault Address and Fault Status registers" on page 100 for information about interpreting the access permission bits.
9	9	[11:9]	SHOULD BE ZERO
[8:5]	[8:5]	[8:5]	Domain control bits
4	4	4	Must be 1.
[3:2]	---	---	Bits C and B indicate whether the area of memory mapped by this page is treated as write-back cachable, write-through cachable, noncached buffered, or noncached nonbuffered.
---	[3:2]	[3:2]	SHOULD BE ZERO

Table 33: Priority encoding of fault status

Bits			
Section	**Coarse**	**Fine**	**Description**
[1:0]	[1:0]	[1:0]	These bits indicate the page size and validity, and are interpreted as shown in Table 34, "Interpreting first-level descriptor bits [1:0]," on page 90.

Table 33: Priority encoding of fault status

Value	Meaning	Description
0 0	Invalid	Generates a section translation fault.
0 1	Coarse page table	Indicates that this is a coarse page table descriptor.
1 0	Section	Indicates that this is a section descriptor.
1 1	Fine page table	Indicates that this is a fine page table descriptor.

Table 34: Interpreting first-level descriptor bits [1:0]

Section descriptor

A section descriptor provides the base address of a 1 MB block of memory. Figure 29 shows the section descriptor format. Table 35 describes the section descriptor bits.

Figure 29: Section descriptor

Bits	Description
[31:20]	Forms the corresponding bits of the physical address for a section.
[19:12]	Always written as 0.
[11:10]	Specify the access permissions for this section.
[09	Always written as 0.

Table 35: Section descriptor bits

Bits	Description
[8:5]	Specifies one of the 16 possible domains (held in the Domain and Access Control register) that contain the primary access controls.
4	Should be written as 1, for backwards compatibility.
[3:2]	Indicate if the area of memory mapped by this section is treated as writeback cachable, write-through cachable, noncached buffered, or noncached nonbuffered.
[1:0]	Must be *10* to indicate a section descriptor.

Table 35: Section descriptor bits

Coarse page table descriptor

A coarse page table descriptor provides the base address of a page table that contains second-level descriptors for either large page or small page accesses. Coarse page tables have 256 entries, splitting the 1 MB that the table describes into 4 KB blocks. Figure 30 shows the coarse page table descriptor format; Table 36 describes the coarse page table descriptor bit assignments.

Note: If a coarse page table descriptor is returned from the first-level fetch, a second-level fetch is initiated.

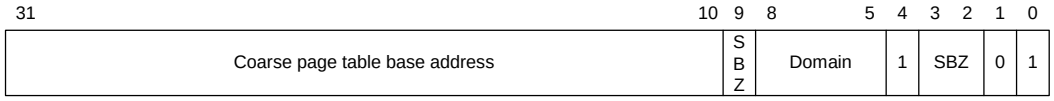


Figure 30: Coarse page table descriptor

Bits	Description
[31:10]	Forms the base for referencing the second-level descriptor (the coarse page table index for the entry derived from the MVA).
9	Always written as 0.
[8:5]	Specifies one of the 16 possible domains (held in the Domain Access Control registers) that contain the primary access controls.
4	Always written as 1.

Table 36: Coarse page table descriptor bits

Bits	Description
[3:2]	Always written as 0.
[1:0]	Must be *01* to indicate a coarse page descriptor.

Table 36: Coarse page table descriptor bits

Fine page table descriptor

A fine page table descriptor provides the base address of a page table that contains second-level descriptors for large page, small page, or tiny page accesses. Fine page tables have 1024 entries, splitting the 1 MB that the table describes into 1 KB blocks. Figure 31 shows the format of a fine page table descriptor. Table 37 describes the fine page table descriptor bit assignments.

Note: If a fine page table descriptor is returned from the first-level fetch, a second-level fetch is initiated.

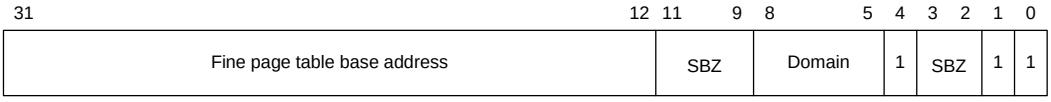


Figure 31: Fine page table descriptor

Bits	Description
[31:12]	Forms the base for referencing the second-level descriptor (the fine page table index for the entry is derived from the MVA).
[11:9]	Always written as 0.
[8:5]	Specifies one of the 16 possible domains (held in the Domain Access Control register) that contain primary access controls.
4	Always written as 1.
[3:2}	Always written as 0.
[1:0]	Must be *11* to indicate a fine page table descriptor.

Table 37: Fine page table descriptor bits

Translating section references

Figure 32 shows the complete section translation sequence.

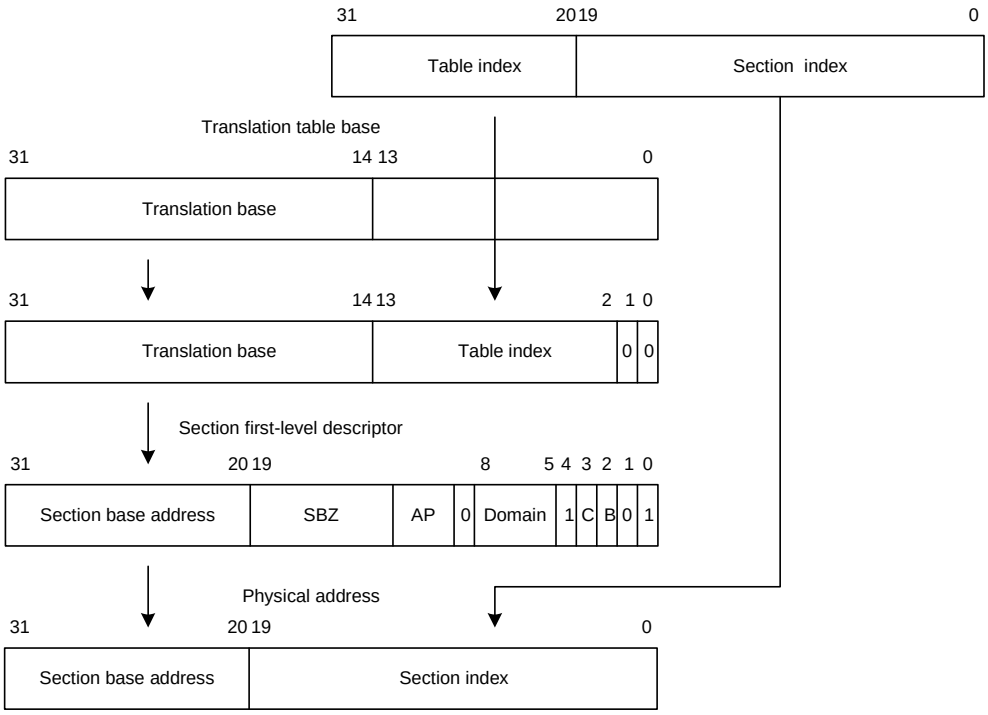


Figure 32: Section translation

Second-level descriptor

The base address of the page table to be used is determined by the descriptor returned (if any) from a first-level fetch — either a coarse page table descriptor or a fine page table descriptor. The page table is then accessed and a second-level descriptor returned.

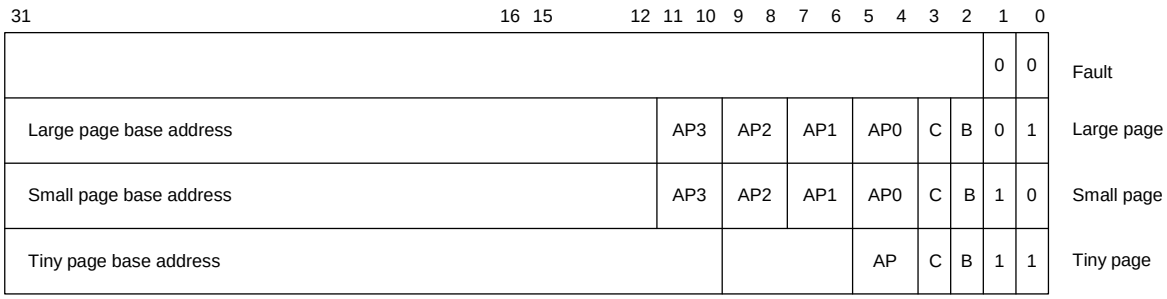


Figure 33: Second-level descriptor

A second-level descriptor defines a tiny, small, or large page descriptor, or is invalid:

- A large page descriptor provides the base address of a 64 KB block of memory.
- A small page descriptor provides the base address of a 4 KB block of memory.
- A tiny page descriptor provides the base address of a 1 KB block of memory.

Coarse page tables provide base addresses for either small or large pages. Large page descriptors must be repeated in 16 consecutive entries. Small page descriptors must be repeated in each consecutive entry.

Fine page tables provide base addresses for large, small, or tiny pages. Large page descriptors must be repeated in 64 consecutive entries. Small page descriptors must be repeated in four consecutive entries. Tiny page descriptors must be repeated in each consecutive entry.

Table 38 describes the second-level descriptor bit assignments.

Bits			
Large	**Small**	**Tiny**	**Description**
[31:16]	[31:12]	[31:10]	Form the corresponding bits of the physical address.
[15:12]	---	[9:6]	SHOULD BE ZERO

Table 38: Second-level descriptor bits

Bits			
Large	Small	Tiny	Description
[11:4]	[11:4]	[5:4]	Access permission bits. See "Domain access control" on page 102 and "Fault checking sequence" on page 103 for information about interpreting the access permission bits.
[3:2]	[3:2]	[3:2]	Indicate whether the area of memory mapped by this page is treated as write-back cachable, write-through cachable, noncached buffered, and noncached nonbuffered.
[1:0]	[1:0]	[1:0]	Indicate the page size and validity, and are interpreted as shown in Table 39, “Interpreting page table entry bits [1:0],” on page 95.

Table 38: Second-level descriptor bits

The two least significant bits of the second-level descriptor indicate the descriptor type; see Table 39.

Value	Meaning	Description
0 0	Invalid	Generates a page translation fault.
0 1	Large page	Indicates that this is a 64 KB page.
1 0	Small page	Indicates that this is a 4 KB page.
1 1	Tiny page	Indicates that this is a 1 KB page.

Table 39: Interpreting page table entry bits [1:0]

Note: Tiny pages do not support subpage permissions and therefore have only one set of access permission bits.

Translating large page references

Figure 34 shows the complete translation sequence for a 64 KB large page.

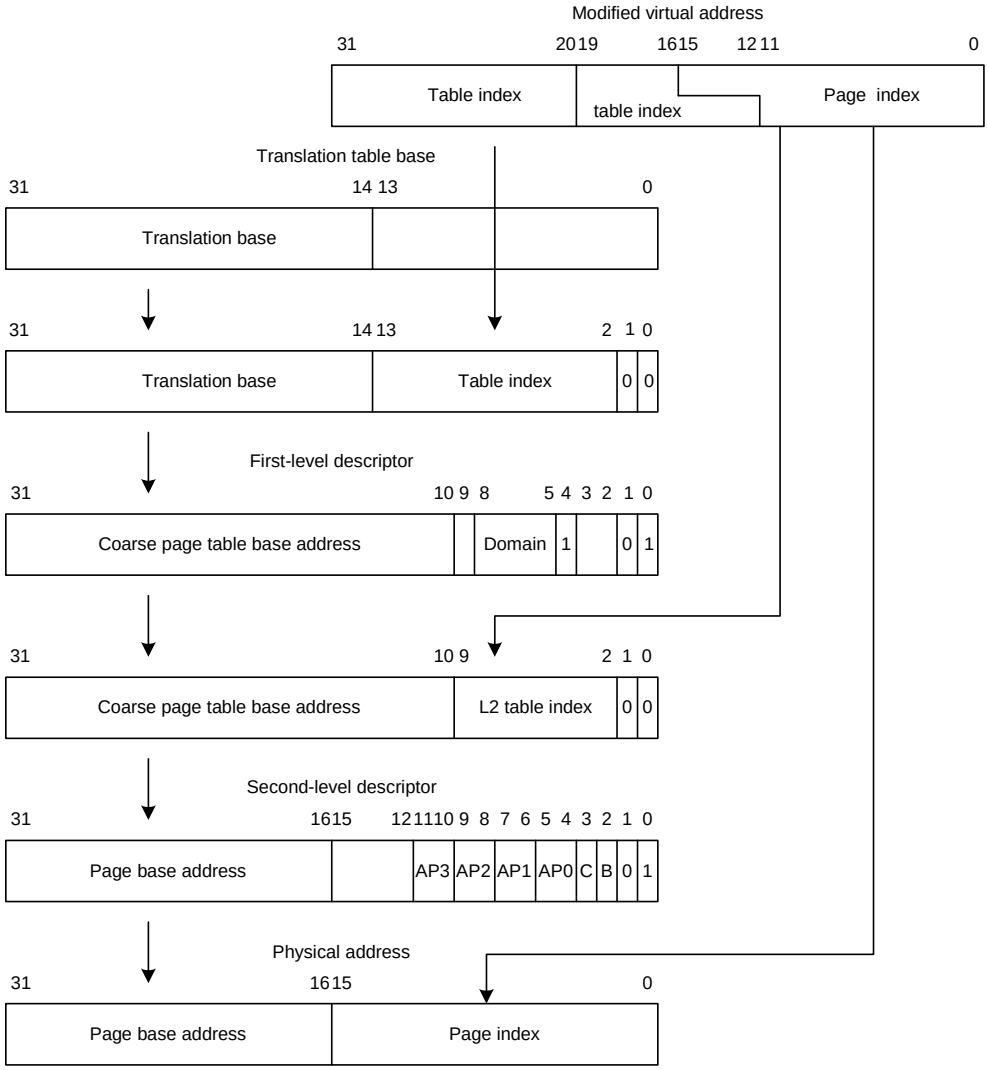


Figure 34: Large page translation from a coarse page table

Because the upper four bits of the page index and low-order four bits of the coarse page table index overlap, each coarse page table entry for a large page must be duplicated 16 times (in consecutive memory locations) in the coarse page table.

If the large page descriptor is included in a fine page table, the high-order six bits of the page index and low-order six bits of the fine page table overlap. Each fine page table entry for a large page must be duplicated 64 times.

Translating small page references

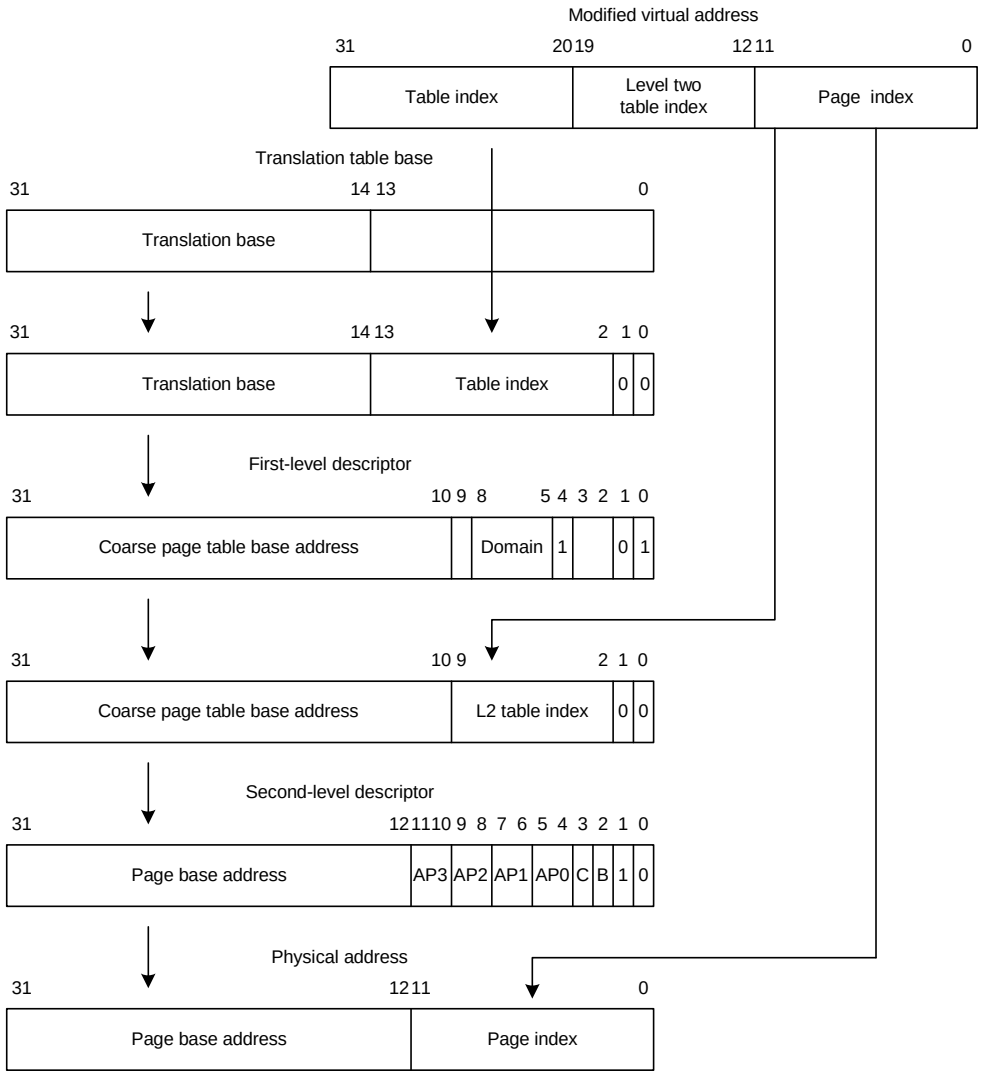


Figure 35: Small page translation from a coarse page table

If a small page descriptor is included in a fine page table, the upper two bits of the page index and low-order two bits of the fine page table index overlap. Each fine page table entry for a small page must be duplicated four times.

Translating tiny page references

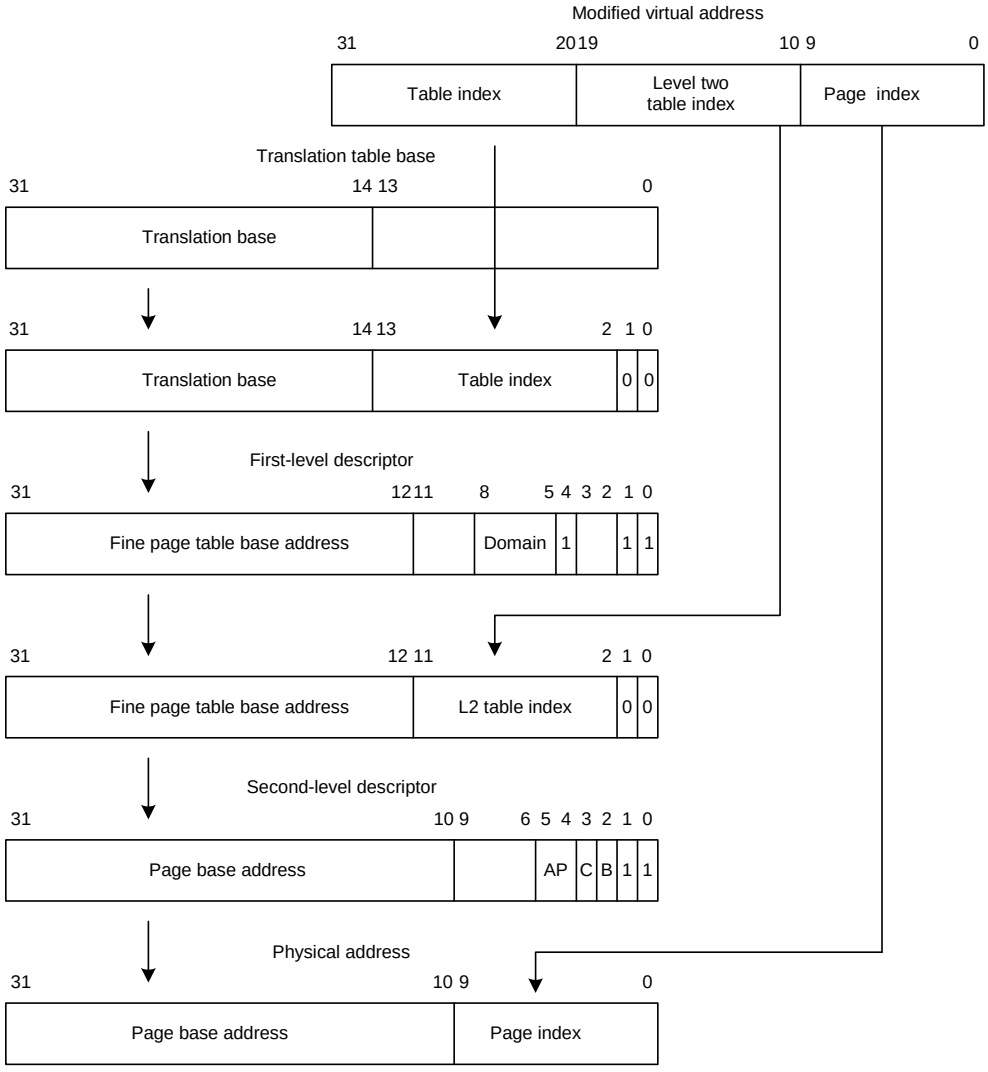


Figure 36: Tiny page translation from a fine page table

Page translation involves one additional step beyond that of a section translation. The first-level descriptor is the fine page table descriptor; this points to the first-level descriptor.

Note: The domain specified in the first-level description and access permissions specified in the first-level description together determine whether the access has permissions to proceed. See "Domain access control" on page 102 for more information.

Subpages

You can define access permissions for subpages of small and large pages. If, during a page table walk, a small or large page has a different subpage permission, only the subpage being accessed is written into the TLB. For example, a 16 KB (large page) subpage entry is written into the TLB if the subpage permission differs, and a 64 KB entry is put in the TLB if the subpage permissions are identical.

When you use subpage permissions and the page entry has to be invalidated, you must invalidate all four subpages separately.

MMU faults and CPU aborts

The MMU generates an abort on these types of faults:

- Alignment faults (data accesses only)
- Translation faults
- Domain faults
- Permission faults

In addition, an external abort can be raised by the external system. This can happen only for access types that have the core synchronized to the external system:

- Page walks
- Noncached reads
- Nonbuffered writes
- Noncached read-lock-write sequence (SWP)

Alignment fault checking is enabled by the A bit in the R1: Control register. Alignment fault checking is not affected by whether the MMU is enabled. Translation, domain, and permission faults are generated only when the MMU is enabled.

The access control mechanisms of the MMU detect the conditions that produce these faults. If a fault is detected as a result of a memory access, the MMU aborts the access and signals the fault condition to the CPU core. The MMU retains status and address information about faults generated by the data accesses in the Data Fault Status register and Fault Address register (see "Fault Address and Fault Status registers" on page 100).

The MMU also retains status about faults generated by instruction fetches in the Instruction Fault Status register.

An access violation for a given memory access inhibits any corresponding external access to the AHB interface, with an abort returned to the CPU core.

Fault Address and Fault Status registers

On a data abort, the MMU places an encoded four-bit value — the *fault status* — along with the four-bit encoded domain number in the Data Fault Status register. Similarly, on a prefetch abort, the MMU places an encoded four-bit value along with the four-bit encoded domain number in the Instruction Fault Status register. In addition, the MVA associated with the data abort is latched into the Fault Address register. If an access violation simultaneously generates more than one source of abort, the aborts are encoded in the priority stated in Table 40. The Fault Address register is not updated by faults caused by instruction prefetches.

Priority	Source	Size	Status	Domain
Highest	Alignment	---	0b00x1	Invalid
	External abort on transmission	First level	0b1100	Invalid
		Second level	0b1110	Valid
	Translation	Section page	0b0101	Invalid
			0b0111	Valid
	Domain	Section page	0b1001	Valid
			0b1011	Valid
	Permission	Section page	0b1101	Valid
			0b1111	Valid
Lowest	External abort	Section page	0b1000	Valid
			0b1010	Valid

Table 40: Priority encoding of fault status

Notes:

- Alignment faults can write either `0b0001` or `0b0011` into Fault Status register `[3:0]`.
- Invalid values can occur in the status bit encoding for domain faults. This happens when the fault is raised before a valid domain field has been read from a page table description.
- Aborts masked by a higher priority abort can be regenerated by fixing the cause of the higher priority abort, and repeating the access.
- Alignment faults are not possible for instruction fetches.
- The Instruction Fault Status register can be updated for instruction prefetch operations `(MCR p15,0,Rd,c7,c13,1)`.

Fault Address register (FAR)

For load and store instructions that can involve the transfer of more than one word (`LDM/STM`, `STRD`, and `STC/LDC`), the value written into the Fault Address register depends on the type of access and, for external aborts, on whether the access crosses a 1 KB boundary. Table 41 shows the Fault Address register values for multi-word transfers.

Domain	Fault Address register
Alignment	MVA of first aborted address in transfer
External abort on translation	MVA of first aborted address in transfer
Translation	MVA of first aborted address in transfer
Domain	MVA of first aborted address in transfer
Permission	MVA of first aborted address in transfer
External about for noncached reads, or nonbuffered writes	MVA of last address before 1KB boundary, if any word of the transfer before 1 KB boundary is externally aborted. MVA of last address in transfer if the first externally aborted word is after the 1 KB boundary.

Table 41: Fault Address register values for multi-word transfers

Compatibility issues

- To enable code to be ported easily to future architectures, it is recommended that no reliance is made on external abort behavior.
- The Instruction Fault Status register is intended for debugging purposes only.

Domain access control

MMU accesses are controlled primarily through the use of domains. There are 16 domains, and each has a two-bit field to define access to it. Client users and Manager users are supported.

The domains are defined in the R3: Domain Access Control register. Figure 16, "R3: Domain Access Control register," on page 65 shows how the 32 bits of the register are allocated to define the 16 two-bit domains.

Table 42 shows how the bits within each domain are defined to specify access permissions.

Value	Meaning	Description
0 0	No access	Any access generates a domain fault.
0 1	Client	Accesses are checked against the access permission bits in the section or page descriptor.
1 0	Reserved	Reserved. Currently behaves like *no access* mode.
1 1	Manager	Accesses are not checked against the access permission bits, so a permission fault cannot be generated.

Table 42: Domain Access Control register, access control bits

Table 43 shows how to interpret the *access permission (AP)* bits, and how the interpretation depends on the R and S bits in the R1: Control register (see "R1: Control register," beginning on page 62).

AP	S	R	Privileged permissions	User permissions
0 0	0	0	No access	No access

Table 43: Interpreting access permission (AP) bits

AP	S	R	Privileged permissions	User permissions
0 0	1	0	Read only	Read only
0 0	0	1	Read only	Read only
0 0	1	1	UNPREDICTABLE	UNPREDICTABLE
0 1	x	x	Read/write	No access
1 0	x	x	Read/write	Read only
1 1	x	x	Read/write	Read/write

Table 43: Interpreting access permission (AP) bits

Fault checking sequence

The sequence the MMU uses to check for access faults is different for sections and pages. Figure 37 shows the sequence for both types of access.

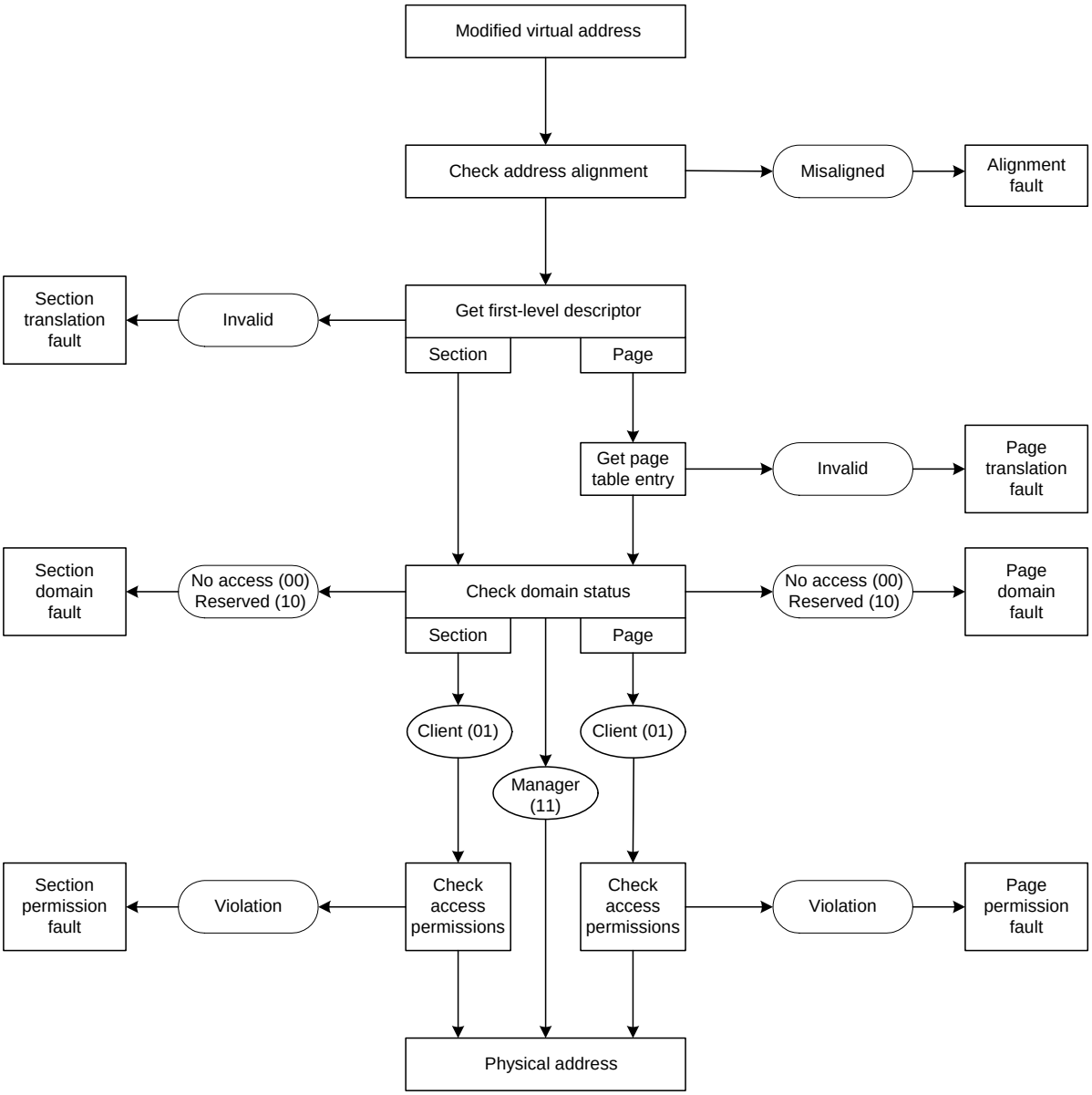


Figure 37: Sequence for checking faults

The conditions that generate each of the faults are discussed in the following sections.

Alignment faults

If alignment fault checking is enabled (the A bit in the R1: Control register is set; see "R1: Control register," beginning on page 62), the MMU generates an alignment fault on any data word access if the address is not word-aligned, or on any halfword access if the address is not halfword-aligned — irrespective of whether the MMU is enabled. An alignment fault is not generated on any instruction fetch or byte access.

Note: If an access generates an alignment fault, the access sequence aborts without reference to other permission checks.

Translation faults

There are two types of translation fault: section and page.

- A section translation fault is generated if the level one descriptor is marked as invalid. This happens if bits [1:0] of the descriptor are both 0.
- A page translation fault is generated if the level one descriptor is marked as invalid. This happens if bits [1:0] of the descriptor are both 0.

Domain faults

There are two types of domain faults: section and page.

- **Section:** The level one descriptor holds the four-bit domain field, which selects one of the 16 two-bit domains in the Domain Access Control register. The two bits of the specified domain are then checked for access permissions as described in Table 43: "Interpreting access permission (AP) bits" on page 102. The domain is checked when the level one descriptor is returned.
- **Page:** The level one descriptor holds the four-bit domain field, which selects one of the 16 two-bit domains in the Domain Access Control register. The two bits of the specified domain are then checked for access permissions as described in Table 43: "Interpreting access permission (AP) bits" on page 102. The domain is checked when the level one descriptor is returned.

If the specified access is either *no access* (00) or *reserved* (10), either a section domain fault or a page domain fault occurs.

Permission faults

If the two-bit domain field returns *client* (01), access permissions are checked as follows:

- **Section:** If the level one descriptor defines a section-mapped access, the AP bits of the descriptor define whether the access is allowed, per Table 43: "Interpreting access permission (AP) bits" on page 102. The interpretation depends on the setting of the S and R bits (see "R1: Control register," beginning on page 62). If the access is not allowed, a section permission fault is generated.
- **Large page or small page:** If the level one descriptor defines a page-mapped access and the level two descriptor is for a large or small page, four access permission fields (AP3 to AP0) are specified, each corresponding to one quarter of the page.

  For small pages, AP3 is selected by the top 1 KB of the page and AP0 is selected by the bottom 1 KB of the page.

  For large pages, AP3 is selected by the top 16 KB of the page and AP0 is selected by the bottom 16 KB of the page. The selected AP bits are then interpreted in the same way as for a section (see Table 43: "Interpreting access permission (AP) bits" on page 102).

  The only difference is that the fault generated is a page permission fault.
- **Tiny page:** If the level one descriptor defines a page-mapped access and the level two descriptor is for a tiny page, the AP bits of the level one descriptor define whether the access is allowed in the same way as for a section. The fault generated is a page permission fault.

External aborts

In addition to MMU-generated aborts, external aborts cam be generated for certain types of access that involve transfers over the AHB bus. These aborts can be used to flag errors on external memory accesses. Not all accesses can be aborted in this way, however.

These accesses can be aborted externally:

- Page walks
- Noncached reads

- Nonbuffered writes
- Noncached read-lock-write (SWP) sequence

For a read-lock-write (SWP) sequence, the write is always attempted if the read externally aborts.

A swap to an NCB region is forced to have precisely the same behavior as a swap to an NCNB region. This means that the write part of a swap to an NCB region can be aborted externally.

Enabling the MMU

Before enabling the MMU using the R1: Control register (see page 62), you must perform these steps:

1. Program the R2: Translation Table Base register (see page 65) and the R3: Domain Access Control register (see page 65).
2. Program first-level and second-level page tables as required, ensuring that a valid translation table is placed in memory at the location specified by the Translation Table Base register.

When these steps have been performed, you can enable the MMU by setting R1: Control register bit 0 (the M bit) to high.

Care must be taken if the translated address differs from the untranslated address, because several instructions following the enabling of the MMU might have been prefetched with MMU off (VA=MVA=PA). If this happens, enabling the MMU can be considered as a branch with delayed execution. A similar situation occurs when the MMU is disabled. Consider this code sequence:

```
MRC p15, 0, R1, c1, C0, 0    ; Read control register
ORR R1, #0x1                 ; Set M bit
MCR p15, 0,R1,C1, C0,0       ; Write control register and enable MMU
Fetch Flat
Fetch Flat
Fetch Translated
```

Note: Because the same register (R1: Control register) controls the enabling of ICache, DCache, and the MMU, all three can be enabled using a single MCR instruction.

Disabling the MMU

Clear bit 0 (the M bit) in the R1: Control register to disable the MMU.

Note: If the MMU is enabled, then disabled, then subsequently re-enabled, the contents of the TLB are preserved. If these are now invalid, the TLB must be invalidated before re-enabling the MMU (see "R8:TLB Operations register" on page 72).

TLB structure

The MMU runs a single unified TLB used for both data accesses and instruction fetches. The TLB is divided into two parts:

- An eight-entry fully-associative part used exclusively for holding locked down TLB entries.
- A set-associative part for all other entries.

Whether an entry is placed in the set-associative part or lockdown part of the TLB depends on the state of the TLB Lockdown register when the entry is written into the TLB (see "R10: TLB Lockdown register" on page 77).

When an entry has been written into the lockdown part of the TLB, it can be removed only by being overwritten explicitly or, when the MVA matches the locked down entry, by an MVA-based TLB invalidate operation.

The structure of the set-associative part of the TLB does not form part of the programmer's model for the ARM926EJ-S processor. No assumptions must be made about the structure, replacement algorithm, or persistence of entries in the set-associative part — specifically:

- Any entry written into the set-associative part of the TLB can be removed at any time. The set-associative part of the TLB must be considered as a temporary cache of translation/page table information. No reliance must be placed on an entry residing or not residing in the set-associative TLB unless that entry already exists in the lockdown TLB. The set-associative part of the TLB can contain entries that are defined in the page tables but do not correspond to address values that have been accessed since the TLB was invalidated.
- The set-associative part of the TLB must be considered as a cache of the underlying page table, where memory coherency must be maintained at all

times. To guarantee coherency if a level one descriptor is modified in main memory, either an invalidate-TLB or Invalidate-TLB-by-entry operation must be used to remove any cached copies of the level one descriptor. This is required regardless of the type of level one descriptor (section, level two page reference, or fault).

- If any of the subpage permissions for a given page are different, each of the subpages are treated separately. To invalidate all entries associated with a page with subpage permissions, four MVA-based invalidate operations are required — one for each subpage.

Caches and write buffer

The ARM926EJ-S processor includes an instruction cache (ICache), data cache (DCache), and write buffer. The size of the caches can be from 4 KB to 128 KB, in power of two increments.

Cache features

- The caches are virtual index, virtual tag, addressed using the modified virtual address (MVA). This avoids cache cleaning and/or invalidating on context switch.
- The caches are four-way set associative, with a cache line length of eight words per line (32 bytes per line), and with two dirty bits in the DCache.
- The DCache supports write-through and write-back (copyback) cache operations, selected by memory region using the C and B bits in the MMU translation tables.
- The caches support *allocate on read-miss*. The caches perform critical-word first cache refilling.
- The caches use pseudo-random or round-robin replacement, selected by the RR bit in R1: Control register.
- Cache lockdown registers enable control over which cache ways are used for allocation on a linefill, providing a mechanism for both lockdown and controlling cache pollution.

- The DCache stores the *Physical Address Tag* (PA tag) corresponding to each DCache entry in the tag RAM for use during cache line write-backs, in addition to the virtual address tag stored in the tag RAM. This means that the MMU is not involved in DCache write-back operations, which removes the possibility of TLB misses to the write-back address.
- Cache maintenance operations provide efficient invalidation of:
  - The entire DCache or ICache
  - Regions of the DCache or ICache
  - Regions of virtual memory

  Cache maintenance operations also provide for efficient cleaning and invalidation of:
  - The entire DCache
  - Regions of the DCache
  - Regions of virtual memory

  The latter allows DCache coherency to be efficiently maintained when small code changes occur; for example, for self-modifying code and changes to exception vectors.

Write buffer

The write buffer is used for all writes to a noncachable bufferable region, write-through region, and write misses to a write-back region. A separate buffer is incorporated in the DCache for holding write-back data for cache line evictions or cleaning of dirty cache lines.

- The main write buffer has a 16-word data buffer and a four-address buffer.
- The DCache write-back buffer has eight data word entries and a single address entry.

The MCR drain write buffer instruction enables both write buffers to be drained under software control.

The MCR wait -for-interrupt causes both write buffers to be drained, and the ARM926EJ-S processor to be put into low-power state until an interrupt occurs.

Enabling the caches

On reset, the ICache and DCache entries all are invalidated and the caches disabled. The caches are not accessed for reads or writes. The caches are enabled using the I, C, and M bits from the R1: Control register, and can be enabled independently of one another. Table 44 gives the I and M bit settings for the ICache, and the associated behavior.

R1 I bit	R1 M bit	ARM926EJ-S behavior
0	-----	ICache disabled. All instruction fetches are fetched from external memory (AHB).
1	0	ICache enabled, MMU disabled. All instruction fetches are cachable, with no protection checks. All addresses are flat-mapped; that is, VA = MVA = PA.
1	1	ICache enabled, MMU enabled. Instruction fetches are cachable or noncachable, depending on the page descriptor C bit (see Table 45: "Page table C bit settings for ICache"), and protection checks are performed. All addresses are remapped from VA to PA, depending on the page entry; that is, the VA is translated to MVA and the MVA is remapped to a PA.

Table 44: R1:Control register I and M bit settings for ICache

Table 45 shows the page table C bit settings for the ICache (R1 I bit = M bit = 1).

Page table C bit	Description	ARM926EJ-S behavior	
0	Noncachable	ICache disabled. All instruction fetches are fetched from external memory.	
1	Cachable	**Cache hit**	Read from the ICache.
		Cache miss	Linefill from external memory.

Table 45: Page table C bit settings for ICache

Table 46 gives the R1: Control register C and M bit settings for DCache, and the associated behavior.

R1 C bit	R1 M bit	ARM926EJ-S behavior
0	0	DCache disabled. All data accesses are to the external memory.
1	0	DCache enabled, MMU disabled. All data accesses are noncachable, nonbufferable, with no protection checks. All addresses are flat-mapped; that is, VA = MVA = PA.
1	1	DCache enabled, MMU enabled. All data accesses are cachable or noncachable, depending on the page descriptor C bit and B bit (see Table 47: "Page table C and B bit settings for DCache"), and protection checks are performed. All addresses are remapped from VA to PA, depending on the MMU page table entry; that is, the VA is translated to an MVA and the MVA is remapped to a PA.

Table 46: R1: Control register I and M bit settings for DCache

Table 47 gives the page table C and B bit settings for the DCache (R1: Control register C bit = M bit = 1), and the associated behavior.

Page table C bit	Page table B bit	Description	ARM926EJ-S behavior
0	0	Noncachable, nonbufferable	DCache disabled. Read from external memory. Write as a nonbuffered store(s) to external memory. DCache is not updated.
0	1	Noncachable, bufferable	DCache disabled. Read from external memory. Write as a buffered store(s) to external memory. DCache is not updated.
1	0	Write-through	DCache enabled: **Read hit** Read from DCache. **Read miss** Linefill. **Write hit** Write to the DCache, and buffered store to external memory. **Write miss** Buffered store to external memory.
1	1	Write-back	DCache enabled: **Read hit** Read from DCache. **Read miss** Linefill. **Write hit** Write to the DCache only. **Write miss** Buffered store to external memory.

Table 47: Page table C and B bit settings for DCache

Cache MVA and Set/Way formats

This section shows how the MVA and set/way formats of ARM926EJ-S caches map to a generic virtually indexed, virtually addressed cache. Figure 38 shows a generic, virtually indexed, virtually addressed cache.

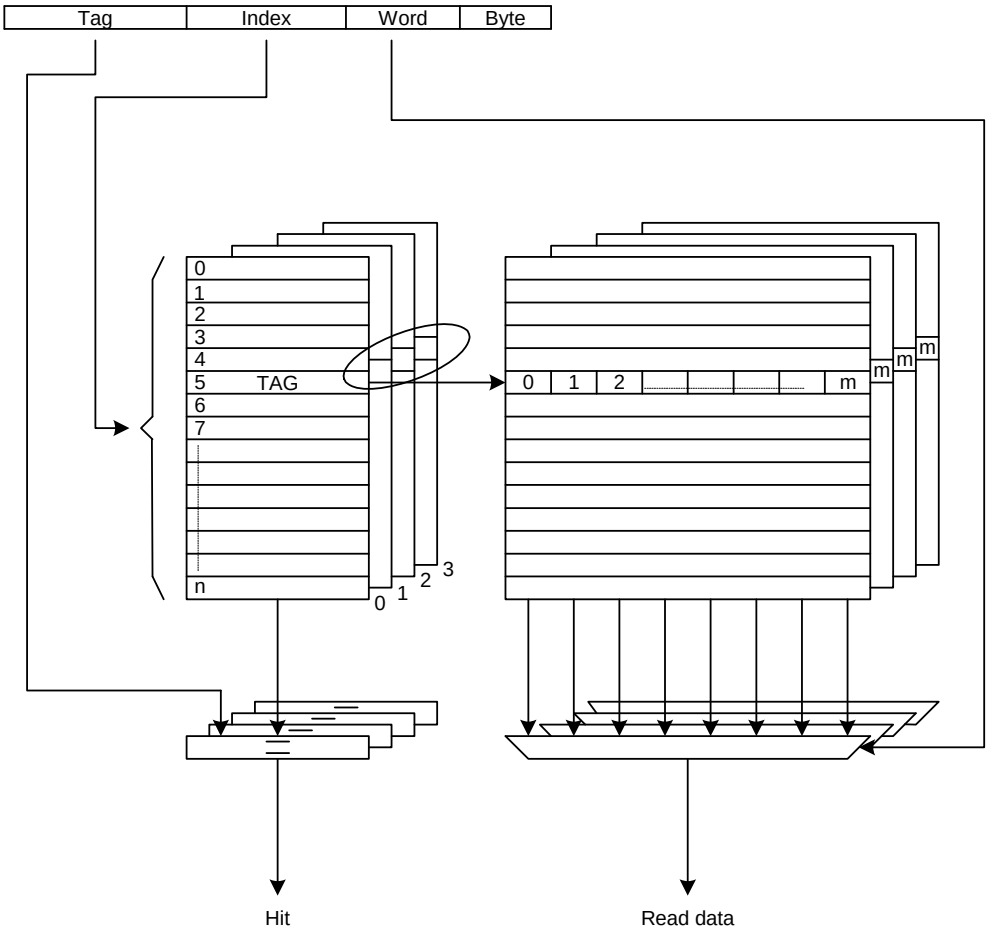


Figure 38: Generic virtually indexed, virtually addressed cache

Figure 39 shows the ARM926EJ-S cache format.

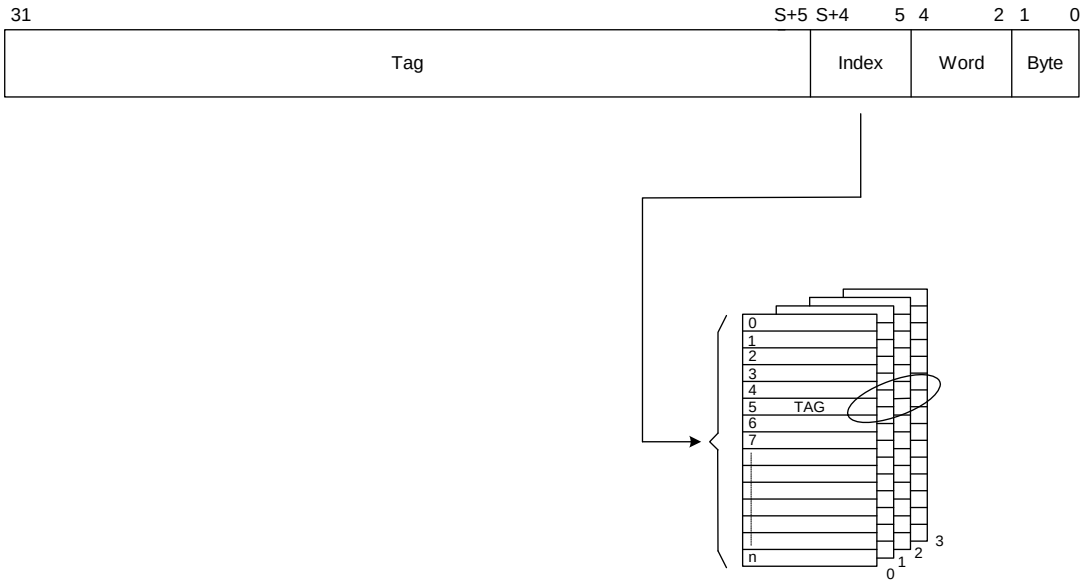


Figure 39: ARM926EJ-S cache associativity

The following points apply to the ARM926EJ-S cache associativity:

- The group of tags of the same index defines a *set*.
- The number of tags in a set is the *associativity*.
- The ARM926EJ-S caches are 4-way associative.
- The range of tags addressed by the index defines a *way.*
- The number of tags is a way is the number of sets, *NSETS*.

Table 48 shows values of S and NSETS for an ARM926EJ-S cache.

ARM926EJ-S	S	NSETS
4 KB	5	32
8 KB	6	64
16 KB	7	128

Table 48: Values of S and NSETS

ARM926EJ-S	S	NSETS
32 KB	8	256
64 KB	9	512
128 KB	10	1024

Table 48: Values of S and NSETS

Figure 40 shows the set/way/word format for ARM926EJ-S caches.

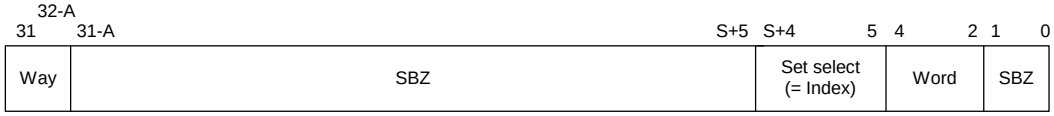


Figure 40: ARM926EJ-S cache set/way/word format

In this figure:

$A = \log_2 \text{associativity}$

For example, with a 4-way cache A = 2:

$S = \log_2 \text{NSETS}$

Noncachable instruction fetches

The ARM926EJ-S processor performs speculative noncachable instruction fetches to increase performance. Speculative instruction fetching is enabled at reset.

Note: It is recommended that you use ICache rather than noncachable code, when possible. Noncachable code previously has been used for operating system boot loaders and for preventing cache pollution. ICache, however, can be enabled without the MMU being enabled, and cache pollution can be controlled using the cache lockdown register.

Self-modifying code

A four-word buffer holds speculatively fetched instructions. Only sequential instructions are fetched speculatively; if the ARM926EJ-S issues a nonsequential instruction fetch, the contents of the buffer are discarded (flushed). In situations on which the contents of the prefetch buffer might become invalid during a sequence of sequential instruction fetches by the processor core (for example, turning the MMU on or off, or turning on the ICache), the prefetch buffer also is flushed. This avoids the necessity of performing an explicit *Instruction Memory Barrier* (IMB) operation, except when self-modifying code is used. Because the prefetch buffer is flushed when the ARM926EJ-S core issues a nonsequential instruction fetch, a branch instruction (or equivalent) can be used to implement the required IMB behavior, as shown in this code sequence:

```
LDMIA       R0,{R1-R5}              ; load code sequence into R1-R5
ADR         R0,self_mod_code
STMIA       R0,{R1-R5}              ; store code sequence (nonbuffered region)
B           self_mod_code           ; branch to modified code
self_mod_code:
```

This IMB application applies only to the ARM926EJ-S processor running code from a noncachable region of memory. If code is run from a cachable region of memory, or a different device is used, a different IMB implementation is required. IMBs are discussed in "Instruction Memory Barrier," beginning on page 117.

AHB behavior

If instruction prefetching is disabled, all instruction fetches appear on the AHB interface as single, nonsequential fetches.

If prefetching is enabled, instruction fetches appear either as bursts of four instructions or as single, nonsequential fetches. No speculative instruction fetching is done across a 1 KB boundary.

All instruction fetches, including those made in Thumb state, are word transfers (32 bits). In Thumb state, a single-word instruction fetch reads two Thumb instructions and a four-word burst reads eight instructions.

Instruction Memory Barrier

Whenever code is treated as data — for example, self-modifying code or loading code into memory — a sequence of instructions called an *instruction memory barrier (IMB)* operation must be used to ensure consistency between the data and instruction streams processed by the ARM926EJ-S processor.

Usually the instruction and data streams are considered to be completely independent by the ARM926EJ-S processor memory system, and any changes in the data side are not automatically reflected in the instruction side. For example, if code is modified in main memory, ICache may contain stale entries. To remove these stale entries, part of all of the ICache must be invalidated.

IMB operation

Use this procedure to ensure consistency between data and instruction sides:

1. **Clean the DCache.** If the cache contains cache lines corresponding to write-back regions of memory, it might contain dirty entries. These entries must be cleaned to make external memory consistent with the DCache. If only a small part of the cache has to be cleaned, it can be done by using a sequence of clean DCache single entry instructions. If the entire cache has to be cleaned, you can use the test and clean operation (see "R7: Cache Operations register," beginning on page 68).
2. **Drain the write buffer.** Executing a drain write buffer causes the ARM926EJ-S core to wait until outstanding buffered writes have completed on the AHB interface. This includes writes that occur as a result of data being written back to main memory because of clean operations, and data for store instructions.
3. **Synchronize data and instruction streams in level two AHB systems.** The level two AHB subsystem might require synchronization between data and instruction sides. It is possible for the data and instruction AHB masters to be attached to different AHB subsystems. Even if both masters are present on the same bus, some form of separate ICache might exist for performance reasons; this must be invalidated to ensure consistency.

   The process of synchronizing instructions and data in level two memory must be invoked using some form of fully blocking operation, to ensure that the end of the operation can be determined using software. It is

recommended that either a nonbuffered store (STR) or a noncached load (LDR) be used to trigger external synchronization.

4 **Invalidate the cache.** The ICache must be invalidated to remove any stale copies of instructions that are no longer valid. If the ICache is not being used, or the modified regions are not in cachable areas of memory, this step might not be required.

5 **Flush the prefetch buffer.** To ensure consistency, the prefetch buffer should be flushed before self-modifying code is executed (see "Self-modifying code" on page 116).

Sample IMB sequences

These sequences correspond to steps 1–4 in "IMB operation."

```
clean loop
     MRC p15, 0, r15, c7, c10, 3; clean entire dcache using test and clean
     BNE clean_loop

     MRC p15, 0, r0, c7, c10, 4 ; drain write buffer
     STR rx,[ry]                  ; nonbuffered store to signal L2 world to
                                  ; synchronize
     MCR p15, 0, r0, c7, c5, 0    ; invalidate icache
```

This next sequence illustrates an IMB sequence used after modifying a single instruction (for example, setting a software breakpoint), with no external synchronization required:

```
STR rx,[ry]                   ; store that modifies instruction at address ry
MCR p15, 0, ry, c7, c10, 1    ; clean dcache single entry (MVA)
MCR p15, 0, r0, c7, c10, 4    ; drain write buffer
MCR p15, 0, ry, c7, c5, 1     ; invalidate icache single entry (MVA)
```

System Control Module

CHAPTER 4

The System Control Module configures and oversees system operations for the NS9775, and defines both the NS9775 AHB arbiter system and system memory address space.

System Control Module features

The System Control Module uses the following to configure and maintain NS9775 system operations:

- AHB arbiter system
- System-level address decoding
- 18 programmable timers
  - Watchdog timer
  - Bus monitor timer for the system bus (a second bus monitor timer, for peripheral devices, is discussed in the BBus Bridge chapter)
  - 16 general purpose timers/counters
- Interrupt controller
- Multiple configuration and status registers
- System Sleep/Wake-up processor

Bus interconnection

The AMBA AHB bus protocol uses a central multiplexor interconnection scheme. All bus masters generate the address and control signals that indicate the transfer that the bus masters want to perform. The arbiter determines which master has its address and control signals routed to all slaves. A central decoder is required to control the read data and response multiplexor, which selects the appropriate signals from the slave that is involved in the transfer.

System bus arbiter

The bus arbitration mechanism ensures that only one bus master has access to the system bus at any time. If you are using a system in which bus bandwidth allocation is critical, you must be sure that your worst-case bus bandwidth allocation goals can be

met. See "Arbiter configuration examples" on page 124 for information about configuring the AHB arbiter.

The NS9775 high-speed bus system is split into two subsystems:

- **High-speed peripheral subsystem:** Connects all high-speed peripheral devices to a port on the external memory controller.
- **CPU subsystem:** Connects the CPU directly to a second port on the external memory controller.

Figure 41 shows an overview of the NS9775 high-speed bus architecture.

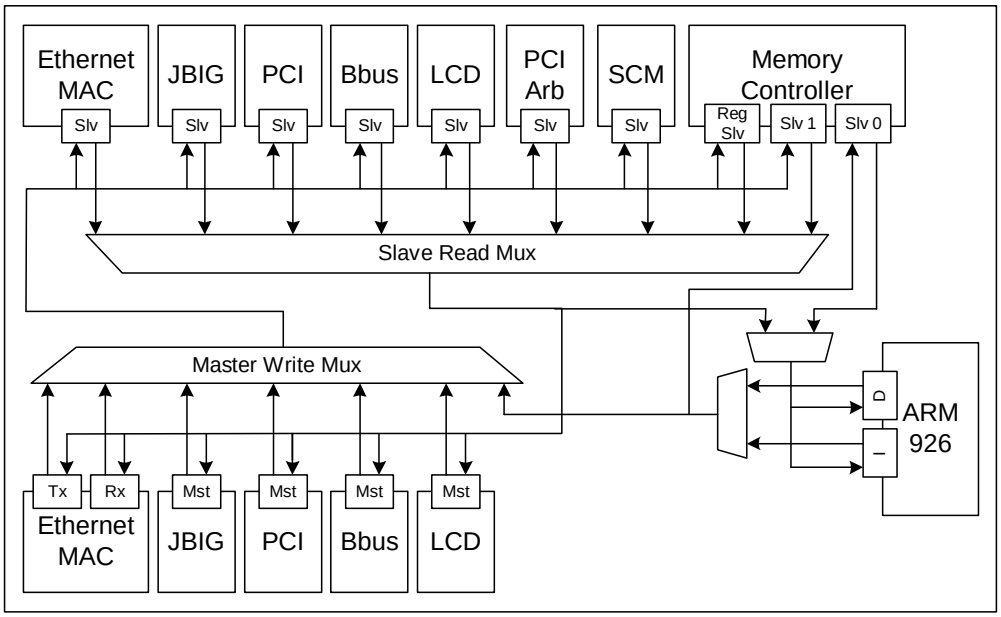


Figure 41: NS9775 bus architecture

The NS9775 high-speed bus contains two arbiters: one for the ARM926 (CPU) and one for the main bus.

- **CPU arbiter.** Splits the bandwidth 50–50 between the data and instruction interfaces. If the CPU access is to external memory, no further arbitration is necessary; the CPU has immediate access to external memory through slave port 0 on the memory controller. If CPU access is to one of the peripherals on the main bus, however, the main arbiter will arbitrate the access.

- **Main arbiter.** Contains a 16-entry Bus Request Configuration (BRC) register. Each BRC entry represents a bus request and grant channel. Each request/grant channel can be assigned to only one bus master at a time. Each bus master can be connected to multiple request/grant channels simultaneously, however, depending on the bus bandwidth requirement of that master.

  Each request/grant channel has a two-bit Bandwidth Reduction Field (BRF) to determine how often each channel can arbitrate for the system bus — 100%, 75%, 50%, or 25%. A BRF value of 25%, for example, causes a channel to be skipped every 3 or 4 cycles. The BRC gates the bus requesting signals going into a 16-entry Bus Request register (BRR). As a default, unassigned channels in the BRC block the corresponding BRR entries from being set by any bus request signals. On powerup, only the CPU is assigned to one of the channels with 100% bandwidth strength as the default setting.

How the bus arbiter works

1. The arbiter evaluates the Bus Request register at every bus clock until one or more bus requests are registered.
2. The arbiter stops evaluating the Bus Request register until a bus grant is issued for the previous evaluation cycle.
3. The arbiter grants the bus to requesting channels, in a round-robin manner, at the rising clock edge of the last address issued for the current transaction (note that each transaction may have multiple transfers), when a SPLIT response is sampled by the arbiter, or when the bus is idling.
4. Each master samples the bus grant signal (`hgrant_x`) at the end of the current transfer, as indicated by the `hready` signal. The bus master takes ownership of the bus at this time.
5. The arbiter updates the `hmaster [3:0]` signals at the same time to indicate the current bus master and to enable the new master's address and control signals to the system bus.

See your AMBA standards documentation for detailed information and illustrations of AMBA AHB transactions.

Ownership

Ownership of the data bus is delayed from ownership of the address/control bus. When `hready` indicates that a transfer is complete, the master that owns the address/control bus can use the data bus — and continues to own that data bus — until the transaction completes.

Note: If a master is assigned more than one request/grant channel, these channels need to be set and reset simultaneously to guarantee that a non-requesting master will not occupy the system bus.

Locked bus sequence

The arbiter observes the `hlock_x` signal from each master to allow guaranteed back-to-back cycles, such as read-modified-write cycles. The arbiter ensures that no other bus masters are granted the bus until the locked sequence has completed. To support SPLIT or RETRY transfers in a locked sequence, the arbiter retains the bus master as granted for an additional transfer to ensure that the last transfer in the locked sequence completed successfully.

If the master is performing a locked transfer and the slave issues a split response, the master continues to be granted the bus until the slave finishes the SPLIT response. (This situation degrades AHB performance.)

Relinquishing the bus

When the current bus master relinquishes the bus, ownership is granted to the next requester.

- If there are no new requesters, ownership is granted to a dummy default master. The default master must perform IDLE transfers to keep the arbiter alive.
- *Bus parking* must be maintained if other masters are waiting for SPLIT transfers to complete.
- If the bus is granted to a default master and continues to be in the IDLE state longer than a specified period of time, an AHB bus arbiter timeout is generated (see "AHB bus error monitoring" on page 127). An AHB bus arbiter timeout can be configured to interrupt the CPU or to reset the chip.

SPLIT transfers

A SPLIT transfer occurs when a slave is not ready to perform the transfer. The slave splits, or masks, its master, taking away the master's bus ownership and allowing other masters to perform transactions until the slave has the appropriate resources to perform its master's transaction.

The bus arbiter supports SPLIT transfers. When a SPLIT response is issued by a slave, the current master is masked for further bus requesting until a corresponding `hsplit_x[15:0]` signal is issued by the slave indicating that the slave is ready to complete the transfer. The arbiter uses the `hsplit_x[15:0]` signals to unmask the corresponding master, and treats the master as the highest-priority requester for the immediate next round of arbitration. The master eventually is granted access to the bus to try the transfer again.

Note: The arbiter automatically blocks bus requests with addresses directed at a "SPLITting" slave until that SPLIT transaction is completed.

Arbiter configuration examples

These examples show how to configure the AHB arbiter to guarantee bandwidth to a given master. These are the conditions in this example:

- 5 AHB masters — Ethernet Rx, Ethernet Tx, PCI, BBus, and LCD.
- Memory clock frequency — 100 MHz (this is the AHB clock frequency).
- Average access time per 32-byte memory access — 16 clock cycles.
- The ARM926EJ-S is guaranteed one-half the total memory bandwidth.

In these examples, the bandwidth for each master can be calculated using this formula:

```
Bandwidth per master:
          = [(100MHz/2) / (16 clock cycles per access x 5 masters)] x 32 bytes
          = 20 Mbytes/master
```

The factor `100MHz/2` is given due to the ARM926EJ-S guarantee of one-half the total memory bandwidth. If the ARM926EJ-S consumes less than the guaranteed memory bandwidth, however, the unused bandwidth will be shared by the other masters.

Note: The worst case scenario is that there are 100 Mbytes total to be split by all 5 masters.

Example 1

Since the 20 Mbyte per master guarantee meets the requirements of all masters, the AHB arbiter will be programmed as follows:

```
BRC0[31:24]        = 8'b1_0_00_0000    channel enabled, 100%, ARM926EJ-S
BRC0[23:16]        = 8'b1_0_00_0001    channel enabled, 100%, Ethernet Rx
BRC0[15:8]         = 8'b1_0_00_0000    channel enabled, 100%, ARM926EJ-S
BRC0[7:0]          = 8'b1_0_00_0010    channel enabled, 100%, Ethernet Tx
BRC1[31:24]        = 8'b1_0_00_0000    channel enabled, 100%, ARM926EJ-S
BRC1[23:16]        = 8'b1_0_00_0100    channel enabled, 100%, PCI
BRC1[15:8]         = 8'b1_0_00_0000    channel enabled, 100%, ARM926EJ-S
BRC1[7:0]          = 8'b1_0_00_0101    channel enabled, 100%, BBus
BRC2[31:24]        = 8'b1_0_00_0000    channel enabled, 100%, ARM926EJ-S
BRC2[23:16]        = 8'b1_0_00_0100    channel enabled, 100%, LCD
BRC2[15:8]         = 8'b0_0_00_0000    channel disabled
BRC2[7:0]          = 8'b0_0_00_0000    channel disabled
BRC3[31:24]        = 8'b0_0_00_0000    channel disabled
BRC3[23:16]        = 8'b0_0_00_0000    channel disabled
BRC3[15:8]         = 8'b0_0_00_0000    channel disabled
BRC[7:0]           = 8'b0_0_00_0000    channel disabled
```

Example 2

In this example, the LCD master needs more than 20 Mbytes and the other masters need less than 20 Mbytes. These are the new requirements:

- Ethernet Rx — 12.5 Mbytes
- Ethernet Tx — 12.5 Mbytes
- PCI — 16 Mbytes
- BBus — 4 Mbytes
- LCD — 25 Mbytes
- Total — 70 Mbytes

This configuration is possible because the total bandwidth is less than the 100 Mbytes available. The LCD master will be configured to have two arbiter slots, resulting in a total of 6 masters.

The available bandwidth per master is calculated using this formula:

```
Bandwidth per master:
          = [(100MHz/2) / (16 clock cycles per access x 6 masters)] x 32 bytes
          = 16.667 Mbytes/master
```

If the LCD is configured for two arbiter channel slots, then, there are 33.334 Mbytes available, which is greater than the 25 Mbytes required. Each of the other masters have 16.667 Mbytes available, which is more than enough to meet their requirements.

Note: When assigning two arbiter channel slots to a master, the slot assignments should be spaced equally.

The AHB arbiter will be programmed as follows:

```
BRC0[31:24]        = 8'b1_0_00_0000     channel enabled, 100%, ARM926EJ-S
BRC0[23:16]        = 8'b1_0_00_0001     channel enabled, 100%, Ethernet Rx
BRC0[15:8]         = 8'b1_0_00_0000     channel enabled, 100%, ARM926EJ-S
BRC0[7:0]          = 8'b1_0_00_0010     channel enabled, 100% Ethernet Tx
BRC1[31:24]        = 8'b1_0_00_0000     channel enabled, 100%, ARM926EJ-S
BRC1[23:16]        = 8'b1_0_00_0110     channel enabled, 100%, LCD first slot
BRC1[15:8]         = 8'b1_0_00_0000     channel enabled, 100%, ARM926EJ-S
BRC1[7:0]          = 8'b1_0_00_0100     channel enabled, 100%, PCI
BRC2[31:24]        = 8'b1_0_00_0000     channel enabled, 100%, ARM926EJ-S
BRC2[23:16]        = 8'b1_0_00_0101     channel enabled, 100%, BBus
BRC2[15:8]         = 8'b1_0_00_0000     channel enabled, 100%, ARM926EJ-S
BRC2[7:0]          = 8'b1_0_00_0110     channel enabled, 100%, LCD second slot
BRC3[31:24]        = 8'b0_0_00_0000     channel disabled
BRC3[23:16]        = 8'b0_0_00_0000     channel disabled
BRC3[15:8]         = 8'b0_0_00_0000     channel disabled
BRC[7:0]           = 8'b0_0_00_0000     channel disabled
```

Note that the BBus requires 4 Mbytes but has been allocated 16.667 Mbytes. The BBus bandwidth can be reduced using the bandwidth reduction field (in the "AHB Bus Arbiter Timeout Period/AHB Bus Monitor Timeout Period register," beginning on page 151). To reduce the available bandwidth by 25% to 4.167 Mbytes, for example, the 2-bit field can be set to `2'b11`. This restricts the BBus master when the system is fully loaded. The new configuration for BBus is:

```
BRC2[23:16]        = 8'b1_0_11_0101     channel enabled, 25%, BBus
```

AHB bus error monitoring

The AHB arbiter monitors for several gross system error conditions:

- **AHB bus arbiter timeout.** Triggers when the AHB bus is granted to a new master and the bus continues to be in the IDLE state longer than the time specified in the AHB Bus Arbiter Timeout Period register (see "AHB Bus Arbiter Timeout Period/AHB Bus Monitor Timeout Period register" on page 151). When the AHB bus arbiter timeout is triggered, the response can be set to one of these options:
  - An interrupt
  - A chip reset
  - “Save the status only; no interrupt or chip reset”
- **AHB bus monitor timeout.** Triggers when a bus master starts a slave access and no slave acknowledges the bus access within the time programmed in the AHB Bus Monitor Timeout Period register (see "AHB Bus Arbiter Timeout Period/AHB Bus Monitor Timeout Period register" on page 151). When the AHB bus monitor timeout is triggered, the response can be set to one of these options:
  - An IRQ interrupt
  - An FIQ interrupt
  - A chip reset
  - “Save the status only; no interrupt or chip reset”
- **AHB slave error response detect.** Monitors for slave ERROR response types. The response can be set to one of these options:
  - An interrupt
  - “Save the status only; no interrupt or chip reset”
- **AHB max burst detect.** Detects burst transfers greater than the value set in the AHB Max Burst Length Detect Configuration field (see "AHB Error Monitoring Configuration register" on page 155). The response can be set to one of these options:
  - An interrupt
  - “Save the status only; no interrupt or chip reset”

Address decoding

A central address decoder provides a select signal — `hsel_x` — for each slave on the bus.

Table 49 shows how the system memory address is set up to allow access to the internal and external resources on the system bus. Note that the external memory chip select ranges can be reset after powerup. The table shows the default powerup values; you can change the ranges by writing to the BASE and MASK registers (see "System Memory Chip Select 0 Dynamic Memory Base and Mask registers" on page 176 through "System Memory Chip Select 3 Dynamic Memory Base and Mask registers" on page 179 for more information).

See the BBus bridge chapter for information about BBus peripheral address decoding.

Address range	Size	System functions
0x0000 0000 – 0x0FFF FFFF	256 MB	System memory chip select 4 Dynamic memory (default)
0x1000 0000 – 0x1FFF FFFF	256 MB	System memory chip select 5 Dynamic memory (default)
0x2000 0000 – 0x2FFF FFFF	256 MB	System memory chip select 6 Dynamic memory (default)
0x3000 0000 – 0x3FFF FFFF	256 MB	System memory chip select 7 Dynamic memory (default)
0x4000 0000 – 0x4FFF FFFF	256 MB	System memory chip select 0 Static memory (default)
0x5000 0000 – 0x5FFF FFFF	256 MB	System memory chip select 1 Static memory (default)
0x6000 0000 – 0x6FFF FFFF	256 MB	System memory chip select 2 Static memory (default)
0x7000 0000 – 0x7FFF FFFF	256 MB	System memory chip select 3 Static memory (default)
0x8000 0000 – 0x8FFF FFFF	256 MB	PCI memory
0x9000 0000 – 0x9FFF FFFF	256 MB	BBus memory

Table 49: System address map

Address range	Size	System functions
0xA000 0000 – 0xA00F FFFF	1 MB	PCI IO
0xA010 0000 – 0xA01F FFFF	1 MB	PCI CONFIG_ADDR
0xA020 0000 – 0xA02F FFFF	1 MB	PCI CONFIG_DATA
0xA030 0000 – 0xA03F FFFF	1 MB	PCI arbiter
0xA040 0000 – 0xA04F FFFF	1 MB	BBUS-to-AHB bridge
0xA050 0000 – 0xA05F FFFF	1 MB	JBIG
0xA060 0000 – 0xA06F FFFF	1 MB	Ethernet Communication Module
0xA070 0000 – 0xA07F FFFF	1 MB	Memory controller
0xA080 0000 – 0xA08F FFFF	1 MB	LCD controller
0xA090 0000 – 0xA09F FFFF	1 MB	System Control Module
0xA0A0 0000 – 0xFFFF FFFF	1526	Reserved

Table 49: System address map

The internal registers, unlike system memory, can be accessed only in *privileged access mode*. Privileged access mode is indicated when `HPROT[1]` is active high.

Table 50 shows the `hmaster[3:0]` assignments for NS9775.

Master Name	hmaster[3:0] assignment
ARM926 I/D	0000
Ethernet Rx	0001
Ethernet Tx	0010
JBIG	0011
PCI	0100
BBus	0101
LCD	0110

Table 50: Hmaster encoding

Programmable timers

NS9775 provides 18 programmable timers:

- Software watchdog timer
- Bus monitor for system bus (see "AHB bus error monitoring" on page 127 and "AHB Bus Arbiter Timeout Period/AHB Bus Monitor Timeout Period register" on page 151)
- 16 general purpose timers

Software watchdog timer

The software watchdog timer, set to specific time intervals, handles gross system misbehaviors. The watchdog timer can be set to timeout in longer ranges of time intervals, typically in seconds.

The software watchdog timer can be enabled or disabled, depending on the operating condition. When enabled, system software must write to the Software Watchdog Timer register before it expires. When the timer does timeout, the system is preconfigured to generate an IRQ, an FIQ, or a RESET to restart the entire system.

General purpose timers/counters

Sixteen general purpose timers/counters (GPTCs), which can be concatenated, provide programmable time intervals to the CPU when used as one or multiple timers. There is one I/O pin associated with each timer.

- When used as a **gated** timer, the GPTC I/O pin is an input qualifier (high/low programmable).
- When used as a **regular** timer (enabled by software) the GPTC I/O pin serves as a terminal count indicator output.

The timers also can be used independently, as up/down counters that monitor the frequency of certain events (events capturing). In these situations, the GPTC I/O pin becomes the clock source of the counter. See "GPIO MUX" on page 38 for information about GPIO pin-to-timer assignments.

Depending on the application, the source clock frequency of the timers/counters can be selected as the CPU clock, the CPU clock with multiple divisor options, or an

external pulse event. The source frequency is indicated in the timer clock select field in the appropriate Timer Control register (see "Timer 0–15 Control registers" on page 174).

With a 16-bit counter and a 16-bit prescaler, each GPTC can measure external event length up to minutes in range, and can be individually enabled or disabled. GPTCs can be configured to reload, with the value defined in the appropriate Timer Reload Count register (see page 156), and generates an interrupt upon terminal count. Each GPTC has an interrupt request connected to the IRQ vector interrupt controller (VIC). The priority level and enable/disable of each interrupt can be programmed in the VIC, and the contents of the timer/counter can be read by the CPU.

The GPTCs can be concatenated to form counters for longer time scales.

These control fields should be in the control register of each GPTC:

- Clock frequency selection
- Mode of operation:
  - Internal timer, with or without external terminal count indicator
  - External gated timer with gate active low
  - External gated timer with gate active high
  - External event counter; frequency must be less than one half the CPU clock frequency
- Timer/counter enable
- Count up or down
- Interrupt enable
- Concatenate to upstream timer/counter. That is, use upstream timer/counter's overflow/underflow output as clock input (16- or 32-bit timer/counter).
- Reload enable

Debug mode

The 16 timers/counters continue to run when the debugger halts the CPU in debug mode. This is not a problem in normal operation.

There is a script available that causes the debugger to continually reset one or more timers while the CPU is halted. Use this debugger script to work around this issue.

```
// This command file initializes the debugger local variables that are
// used by the user defined On-Stop and Idle-Mode command descriptors.
//
// NOTE:   DO NOT CHANGE THIS FILE. This file configures the resources
//         needed to use this feature. To specify an On-Stop or Idle-Mode
//         command for your target, add an EW command to your board init
//         file using the syntax shown below to define the sequence of
//         operations, enable or disable them, and set the Idle-Mode timer
//         interval.
//
// ..........................................................................
//
// The On-Stop command descriptor performs a user defined sequence of
// memory operations whenever program execution stops. This may be
// used, for example, to disable a watchdog timer or other peripheral.
// The On-Stop command descriptor is a 16 word (max) buffer in the
// following format:
//
//     ew MAJIC_ON_STOP_CMD = en, { @op, addr [ , data [ , mask ] ] }...
//
// The Idle-Mode command descriptor performs a user defined sequence of
// memory operations periodically while the program is stopped. This
// may be used, for example, to periodically access a watchdog timer
// or another peripheral. The Idle-Mode command descriptor is a 16 word
// (max) buffer in the following format:
//
//     ew MAJIC_IDLE_MODE_CMD = int, { @op, addr [ , data [ , mask ] ] }...
//
// Parameters:
//
//     en      enable:  0 to disable, 1 to enable
//     int     interval:0 to disable, non-0 for interval in milliseconds
//     op      opcode:  Any of the $ucd_xxxx aliases below
//     addr    Address of the access (must be properly aligned for op size)
//     data    Data value for $ucd_wr and $ucd_rmw (omit for $ucd_rd)
//     mask    Data maskfor $ucd_rmw (1's are bits to replace with data)
//
// ..........................................................................
//
```

```
// Examples:
//
//     ew MAJIC_ON_STOP_CMD = 1, @$ucd_rd8, FFF00003
//
// Defines an On-Stop command that reads the byte at 0xFFF00003 upon
// stopping.
//
//     ew MAJIC_ON_STOP_CMD = 1, @$ucd_rmw16, 80000000, C00, F00
//
// Defines an On-Stop command that reads a 16-bit value from 80000000,
// masks off bits 11..8, sets those bits to 1100, and writes the result
// back to 80000000.
//
//     ew MAJIC_IDLE_MODE_CMD = 0n250, @$ucd_wr32, 0x40000000, 0n5000
//
// Defines the Idle-Mode command that writes the 32-bit value 5000 (decimal)
// to the register at 0x40000000 every 250 milliseconds.
//
//     ew MAJIC_ON_STOP_CMD= 0
//     ew MAJIC_IDLE_MODE_CMD= 0
//
// Disables the On-Stop and Idle-Mode command descriptors.
//
// ....................................................................
//
ew $ucd_rd8   = 101    //  8-bit read operation
ew $ucd_rd16  = 102    // 16-bit read operation
ew $ucd_rd32  = 104    // 32-bit read operation
ew $ucd_wr8   = 201    //  8-bit write operation
ew $ucd_wr16  = 202    // 16-bit write operation
ew $ucd_wr32  = 204    // 32-bit write operation
ew $ucd_rmw8  = 301    //  8-bit RdModWr operation
ew $ucd_rmw16 = 302    // 16-bit RdModWr operation
ew $ucd_rmw32 = 304    // 32-bit RdModWr operation
//
// <eof>
```

Interrupt controller

The interrupt system is a simple two-tier priority scheme. Two lines access the CPU core and can interrupt the processor: IRQ (normal interrupt) and FIQ (fast interrupt). FIQ has a higher priority than IRQ.

FIQ interrupts

Most sources of interrupts on NS9775 are from the IRQ line. There is only one FIQ source for timing-critical applications. The FIQ interrupt generally is reserved for timing-critical applications for these reasons:

- The interrupt service routine is executed directly without determining the source of the interrupt.
- Interrupt latency is reduced. The banked registers available for FIQ interrupts are more efficient because a context save is not required.

Note: The interrupt source assigned to the FIQ must be assigned to the highest priority, which is 0.

IRQ interrupts

IRQ interrupts come from several different sources in NS9775, and are managed using the Interrupt Config registers (see "Int (Interrupt) Config (Configuration) registers (0–31)" on page 158). IRQ interrupts can be enabled or disabled on a per-level basis using the Interrupt Enable registers. These registers serve as masks for the different interrupt levels. Each interrupt level has two registers:

- **Interrupt Configuration register.** Use this register to assign the source for each interrupt level, invert the source polarity, select IRQ or FIQ, and enable the level.
- **Interrupt Vector Address register.** Contains the address of the interrupt service routine.

Figure 42 illustrates a 32-vector interrupt controller.

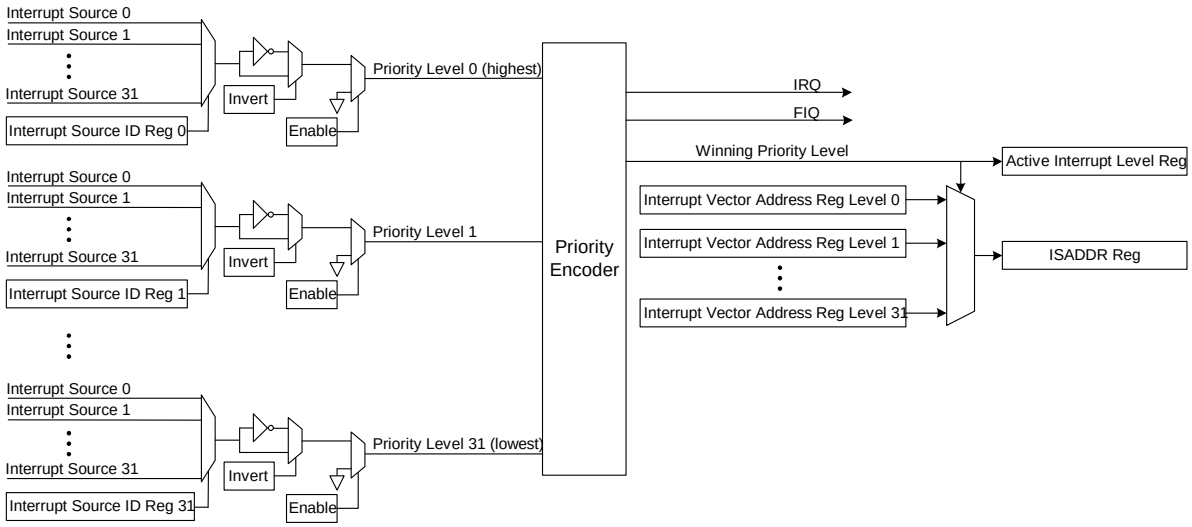


Figure 42: Interrupt controller block diagram

The IRQ interrupts are enabled by the respective enabling bits. Once enabled, the interrupt source programmed in the Interrupt Configuration register for each priority level connects the interrupt to one of 32 priority lines going into the *priority encoder block*. The priority encoder block has a fixed order, with line 0 as the highest priority. The interrupt with the highest priority level has its encoded priority level displayed, to select the appropriate vector for the ISRADDR register (see "ISRADDR register" on page 160). The CPU, once interrupted, can read the ISRADDR register to get the address of the Interrupt Service Routine. A read to the ISRADDR register updates the priority encoder block, which masks the current and any lower priority interrupt requests. Writing to this address indicates to the priority hardware that the current interrupt is serviced, allowing lower priority interrupts to become active.

The priority encoder block enables 32 prioritized interrupts to be serviced in nested fashion. A software interrupt can be implemented by writing to a software interrupt register. The software interrupt typically is assigned level 1 or level 2 priority.

Interrupt sources

An Interrupt Status register shows the current active interrupt requests. The Raw Interrupts register shows the status of the unmasked interrupt requests.

The NS9775 interrupt sources are assigned as shown:

Interrupt ID	Interrupt source
0	Watchdog Timer
1	AHB Bus Error
2	BBus Aggregate Interrupt
3	JBIG Module Interrupt
4	Ethernet Module Receive Interrupt
5	Ethernet Module Transmit Interrupt
6	Ethernet Phy Interrupt
7	LCD Module interrupt
8	PCI Bridge Module Interrupt
9	PCI Arbiter Module Interrupt
10	PCI External Interrupt 0
11	PCI External Interrupt 1
12	PCI External Interrupt 2
13	PCI External Interrupt 3
14	I2C Interrupt
15	BBus DMA Interrupt
16	Timer Interrupt 0
17	Timer Interrupt 1
18	Timer Interrupt 2
19	Timer Interrupt 3
20	Timer Interrupt 4
21	Timer Interrupt 5
22	Timer Interrupt 6
23	Timer Interrupt 7
24	Timer Interrupt 8 and 9
25	Timer Interrupt 10 and 11

Interrupt ID	Interrupt source
26	Timer Interrupt 12 and 13
27	Timer Interrupt 14 and 15
28	External Interrupt 0
29	External Interrupt 1
30	External Interrupt 2
31	External Interrupt 3

Vectored interrupt controller (VIC) flow

A vectored interrupt controller allows a reasonable interrupt latency for IRQ-line interrupts. When an interrupt occurs, the CPU processor determines whether the interrupt is from a FIQ or IRQ line. If the interrupt comes from the FIQ vector, the interrupt service routine can be executed without knowing the interrupt source.

If the interrupt comes from the IRQ vector, the CPU performs these steps:

1. Reads the service routine address from the VIC's ISRADDR register. The read updates the VIC's priority hardware to prevent current or any lower priority interrupts from interrupting until the higher priority interrupt has occurred.
2. Branches to the interrupt service routine and stacks the workspace so the IRQ can be enabled.
3. Executes the interrupt service routine.
4. Clears the current interrupt from the source.
5. Disables the IRQ and restores the workplace.
6. Writes to the ISRADDR register to clear the current interrupt path in the VIC's priority hardware. Any value can be written.
7. Returns from the interrupt service routine.

System attributes

System software can configure these NS9775 system attributes:

- Little endian/big endian mode

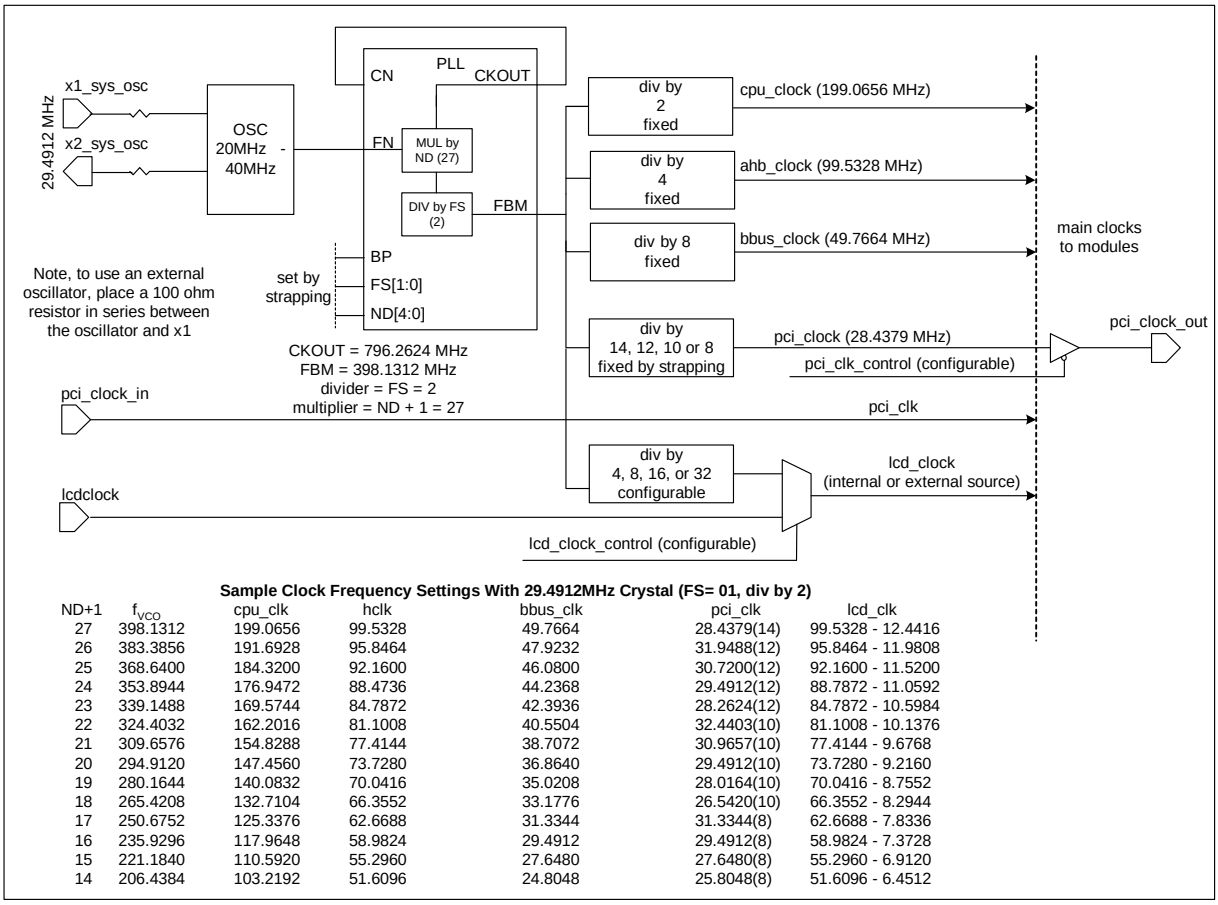
- Watchdog timer enable
- Watchdog timeout generates IRQ/FIQ/RESET
- Watchdog timeout interval
- Enable/disable ERROR response for misaligned data access
- System module clock enables
- Enable access to internal registers in USER mode
- Bus monitor enable
- Bus monitor timeout interval
- Bus arbiter timer enable
- Bus arbiter timeout period
- Bus arbiter timeout response (IRQ/FIQ/RESET)
- Bus bandwidth configuration
- Wake-up processor enable

PLL configuration

PLL operating parameters are initialized on a powerup hardware reset. Software reads the powerup hardware settings by reading the status fields in the PLL Configuration register (see "PLL Configuration register" on page 171). Software can change the PLL configuration after a powerup reset by writing to the appropriate SW field in the PLL Configuration register (see "PLL Configuration register," beginning on page 171). Once the new settings have been written, the PLL SW change bit must be set (see page 172). The PLL settings then are written to the PLL, and the system is reset.

The PLL can be configured at powerup by placing pulldowns on the external memory address pins. NS9775 provides internal pullups to produce a default configuration; see "Bootstrap initialization" on page 139 for information about the powerup configuration.

Figure 43 shows how the PLL clock is used to provide the NS9775 system clocks.



Sample Clock Frequency Settings With 29.4912MHz Crystal (FS= 01, div by 2)

ND+1	f_{VCO}	cpu_clk	hclk	bbus_clk	pci_clk	lcd_clk
27	398.1312	199.0656	99.5328	49.7664	28.4379(14)	99.5328 - 12.4416
26	383.3856	191.6928	95.8464	47.9232	31.9488(12)	95.8464 - 11.9808
25	368.6400	184.3200	92.1600	46.0800	30.7200(12)	92.1600 - 11.5200
24	353.8944	176.9472	88.4736	44.2368	29.4912(12)	88.7872 - 11.0592
23	339.1488	169.5744	84.7872	42.3936	28.2624(12)	84.7872 - 10.5984
22	324.4032	162.2016	81.1008	40.5504	32.4403(10)	81.1008 - 10.1376
21	309.6576	154.8288	77.4144	38.7072	30.9657(10)	77.4144 - 9.6768
20	294.9120	147.4560	73.7280	36.8640	29.4912(10)	73.7280 - 9.2160
19	280.1644	140.0832	70.0416	35.0208	28.0164(10)	70.0416 - 8.7552
18	265.4208	132.7104	66.3552	33.1776	26.5420(10)	66.3552 - 8.2944
17	250.6752	125.3376	62.6688	31.3344	31.3344(8)	62.6688 - 7.8336
16	235.9296	117.9648	58.9824	29.4912	29.4912(8)	58.9824 - 7.3728
15	221.1840	110.5920	55.2960	27.6480	27.6480(8)	55.2960 - 6.9120
14	206.4384	103.2192	51.6096	24.8048	25.8048(8)	51.6096 - 6.4512

Figure 43: NS9775 system clock generation (PLL)

Bootstrap initialization

The PLL and other system configuration settings can be configured at powerup before the CPU boots. External pins are used to configure the necessary control register bits at powerup. External pulldown resistors can be used to configure the PLL and system configuration registers depending on the application. The recommended value is 2.2k ohm to 2.4k ohm.

Table 51 indicates how each bit is used to configure the powerup settings, where 1 indicates the internal pullup resistor and 0 indicates an external pulldown resistor. Table 52 shows PLL ND[4:0] multiplier values.

Pin name	Configuration bits
rtck	**PCI arbiter configuration** 0 External PCI arbiter 1 Internal PCI arbiter
print_out	**Chip select 1 byte_lane_enable_n/write_enable_n configuration** 0 write_enable_n for byte-wide devices (default) 1 byte_lane_enable_n (2.4K pulldown added)
bp_stat[3:2]	**Chip select 1 data width** 00 16 bits 01 8 bits 11 32 bits
bp_stat[1]	**Memory clock/control delay mode** **Note:** An external pulldown resistor must be used to select command delayed mode. Clock delayed mode is reserved for future use. 0 Command delayed mode Commands are launched on a 90-degree phase-shifted AHB clock, and the AHB clock is routed to the external dynamic memory. 1 Clock delayed mode Reserved for future use.
bp_stat[0]	**CardBus mode** 0 CardBus mode 1 PCI mode
gpio[49]	**Chip select polarity** 0 Active high 1 Active low
gpio[44]	**Endian mode** 0 Big endian 1 Little endian
reset_done	**Bootup mode** 0 Boot from SDRAM using serial SPI EEPROM 1 Boot from flash/ROM

Table 51: Configuration pins — Bootstrap initialization

Pin name	Configuration bits
gpio[19]	**PLL BP (PLL bypass)** 0 PLL bypassed 1 PLL not bypassed
gpio[17], gpio[12], gpio[10], gpio[8], gpio[4]	**PLL ND[4:0] (PLL multiplier, ND + 1)** See Table 52: "PLL ND[4:0] multiplier values."
gpio[2], gpio[0]	**PLL FS[1:0] (PLL frequency select)** **FS** **Divide by** 00 1 01 2 10 4 11 8

Table 51: Configuration pins — Bootstrap initialization

Register configuration: gpio 17, 12, 10, 8, 4	Multiplier
11010	**32**
00100	**31**
11000	**30**
11001	**29**
11110	**28**
11111	**27**
11100	**26**
11101	**25**
10010	**24**
10011	**23**
10000	**22**
10001	**21**
10110	**20**

Table 52: PLL ND[4:0] multiplier values

Register configuration: gpio 17, 12, 10, 8, 4	Multiplier
10111	**19**
10100	**18**
10101	**17**
01010	**16**
01011	**15**
01000	**14**
01001	**13**
01110	**12**
01111	**11**
01100	**10**
01101	**9**
00010	**8**
00011	**7**
00000	**6**
00001	**5**
00110	**4**
00111	**3**
00100	**2**
00101	**1**

Table 52: PLL ND[4:0] multiplier values

There are 32 additional GPIO pins that are used to create a general purpose, user-defined ID register (see "Gen ID register" on page 184). These external signals are registered at powerup.

gpio[41]	gpio[40]	gpio[39]	gpio[38]
gpio[37]	gpio[36]	gpio[35]	gpio[34]
gpio[33]	gpio[32]	gpio[31]	gpio[30]
gpio[29]	gpio[28]	gpio[27]	gpio[26]
gpio[25]	gpio[23]	gpio[22]	gpio[21]
gpio[18]	gpio[16]	gpio[15]	gpio[14]
gpio[13]	gpio[11]	gpio[9]	gpio[7]
gpio[6]	gpio[5]	gpio[3]	gpio[1]

Read these signals for general purpose status information.

System configuration registers

Table 53 lists the configuration and status registers for the high-speed AHB bus system.

All configuration registers must be accessed as 32-bit words and as single accesses only. No bursting is allowed.

Offset	[31:24]	[23:16]	[15:8]	[7:0]
A090 0000	AHB Arbiter Gen Configuration			
A090 0004	BRC0			
A090 0008	BRC1			
A090 000C	BRC2			
A090 0010	BRC3			
A090 0014	AHB Bus Arbiter Timeout Period		AHB Bus Monitor Timeout Period	

Table 53: System Control module registers

Offset	[31:24]	[23:16]	[15:8]	[7:0]
A090 0018	AHB Error Detect Status 1			
A090 001C	AHB Error Detect Status 2			
A090 0020	AHB Error Monitoring Configuration			
A090 0024–A090 0040	Reserved			
A090 0044	Timer 0 Reload Count register			
A090 0048	Timer 1 Reload Count register			
A090 004C	Timer 2 Reload Count register			
A090 0050	Timer 3 Reload Count register			
A090 0054	Timer 4 Reload Count register			
A090 0058	Timer 5 Reload Count register			
A090 005C	Timer 6 Reload Count register			
A090 0060	Timer 7 Reload Count register			
A090 0064	Timer 8 Reload Count register			
A090 0068	Timer 9 Reload Count register			
A090 006C	Timer 10 Reload Count register			
A090 0070	Timer 11 Reload Count register			
A090 0074	Timer 12 Reload Count register			
A090 0x078	Timer 13 Reload Count register			
A090 007C	Timer 14 Reload Count register			
A090 0080	Timer 15 Reload Count register			
A090 0084	Timer 0 Read register			
A090 0088	Timer 1 Read register			
A090 008C	Timer 2 Read register			
A090 0090	Timer 3 Read register			
A090 0094	Timer 4 Read register			
A090 0098	Timer 5 Read register			
A090 009C	Timer 6 Read register			

Table 53: System Control module registers

Offset	[31:24]	[23:16]	[15:8]	[7:0]
A090 00A0	Timer 7 Read register			
A090 00A4	Timer 8 Read register			
A090 00A8	Timer 9 Read register			
A090 00AC	Timer 10 Read register			
A090 00B0	Timer 11 Read register			
A090 00B4	Timer 12 Read register			
A090 00B8	Timer 13 Read register			
A090 00BC	Timer 14 Read register			
A090 00C0	Timer 15 Read register			
A090 00C4	Interrupt Vector Address Register Level 0			
A090 00C8	Interrupt Vector Address Register Level 1			
A090 00CC	Interrupt Vector Address Register Level 2			
A090 00D0	Interrupt Vector Address Register Level 3			
A090 00D4	Interrupt Vector Address Register Level 4			
A090 00D8	Interrupt Vector Address Register Level 5			
A090 00DC	Interrupt Vector Address Register Level 6			
A090 00E0	Interrupt Vector Address Register Level 7			
A090 00E4	Interrupt Vector Address Register Level 8			
A090 00E8	Interrupt Vector Address Register Level 9			
A090 00EC	Interrupt Vector Address Register Level 10			
A090 00F0	Interrupt Vector Address Register Level 11			
A090 00F4	Interrupt Vector Address Register Level 12			
A090 00F8	Interrupt Vector Address Register Level 13			
A090 00FC	Interrupt Vector Address Register Level 14			
A090 0100	Interrupt Vector Address Register Level 15			
A090 0104	Interrupt Vector Address Register Level 16			
A090 0108	Interrupt Vector Address Register Level 17			

Table 53: System Control module registers

Offset	[31:24]	[23:16]	[15:8]	[7:0]
A090 010C	Interrupt Vector Address Register Level 18			
A090 0110	Interrupt Vector Address Register Level 19			
A090 0114	Interrupt Vector Address Register Level 20			
A090 0118	Interrupt Vector Address Register Level 21			
A090 011C	Interrupt Vector Address Register Level 22			
A090 0120	Interrupt Vector Address Register Level 23			
A090 0124	Interrupt Vector Address Register Level 24			
A090 0128	Interrupt Vector Address Register Level 25			
A090 012C	Interrupt Vector Address Register Level 26			
A090 0130	Interrupt Vector Address Register Level 27			
A090 0134	Interrupt Vector Address Register Level 28			
A090 0138	Interrupt Vector Address Register Level 29			
A090 013C	Interrupt Vector Address Register Level 30			
A090 0140	Interrupt Vector Address Register Level 31			
A090 0144	Int Config 0	Int Config 1	Int Config 2	Int Config 3
A090 0148	Int Config 4	Int Config 5	Int Config 6	Int Config 7
A090 014C	Int Config 8	Int Config 9	Int Config 10	Int Config 11
A090 0150	Int Config 12	Int Config 13	Int Config 14	Int Config 15
A090 0154	Int Config 16	Int Config 17	Int Config 18	Int Config 19
A090 0158	Int Config 20	Int Config 21	Int Config 22	Int Config 23
A090 015C	Int Config 24	Int Config 25	Int Config 26	Int Config 27
A090 0160	Int Config 28	Int Config 29	Int Config 30	Int Config 31
A090 0164	ISRADDR			
A090 0168	Interrupt Status Active			
A090 016C	Interrupt Status Raw			
A090 0170	Timer Interrupt Status register			
A090 0174	Software Watchdog Configuration			

Table 53: System Control module registers

Offset	[31:24]	[23:16]	[15:8]	[7:0]
A090 0178	Software Watchdog Timer			
A090 017C	Clock Configuration register			
A090 0180	Reset and Sleep Control register			
A090 0184	Miscellaneous System Configuration register			
A090 0188	PLL Configuration register			
A090 018C	Active Interrupt Level register			
A090 0190	Timer 0 Control register			
A090 0194	Timer 1 Control register			
A090 0198	Timer 2 Control register			
A090 019C	Timer 3 Control register			
A090 01A0	Timer 4 Control register			
A090 01A4	Timer 5 Control register			
A090 01A8	Timer 6 Control register			
A090 01AC	Timer 7 Control register			
A090 01B0	Timer 8 Control register			
A090 01B4	Timer 9 Control register			
A090 01B8	Timer 10 Control register			
A090 01BC	Timer 11 Control register			
A090 01C0	Timer 12 Control register			
A090 01C4	Timer 13 Control register			
A090 01C8	Timer 14 Control register			
A090 01CC	Timer 15 Control register			
A090 01D0	System Memory Chip Select 0 Dynamic Memory Base			
A090 01D4	System Memory Chip Select 0 Dynamic Memory Mask			
A090 01D8	System Memory Chip Select 1 Dynamic Memory Base			
A090 01DC	System Memory Chip Select 1 Dynamic Memory Mask			
A090 01E0	System Memory Chip Select 2 Dynamic Memory Base			

Table 53: System Control module registers

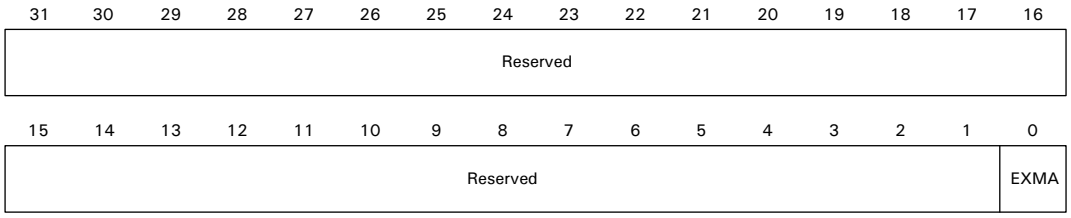
Offset	[31:24]	[23:16]	[15:8]	[7:0]
A090 01E4	System Memory Chip Select 2 Dynamic Memory Mask			
A090 01E8	System Memory Chip Select 3 Dynamic Memory Base			
A090 01EC	System Memory Chip Select 3 Dynamic Memory Mask			
A090 01F0	System Memory Chip Select 0 Static Memory Base			
A090 01F4	System Memory Chip Select 0 Static Memory Mask			
A090 01F8	System Memory Chip Select 1 Static Memory Base			
A090 01FC	System Memory Chip Select 1 Static Memory Mask			
A090 0200	System Memory Chip Select 2 Static Memory Base			
A090 0204	System Memory Chip Select 2 Static Memory Mask			
A090 0208	System Memory Chip Select 3 Static Memory Base			
A090 020C	System Memory Chip Select 3 Static Memory Mask			
A090 0210	GenID— General purpose, user-defined ID register			
A090 0214	External Interrupt 0 Control register			
A090 0218	External Interrupt 1 Control register			
A090 021C	External Interrupt 2 Control register			
A090 0220	External Interrupt 3 Control register			

Table 53: System Control module registers

AHB Arbiter Gen Configuration register

Address: A090 0000

The AHB Arbiter Gen Configuration register contains miscellaneous control settings for the AHB bus arbiter.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:01	N/A	Reserved	N/A	N/A
D00	R/W	EXMA	0x0	**CPU external memory access mode** 0 Enable direct access to external memory through Slv1 1 Disable direct access to external memory, arbitrate with other masters through Slv0

Table 54: AHB Arbiter Gen Configuration register

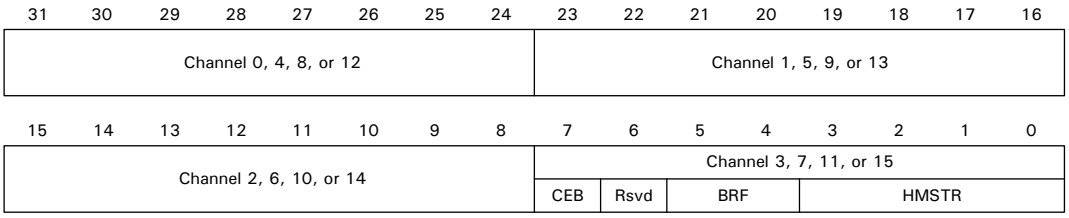
BRC0, BRC1, BRC2, and BRC3 registers

Address: A090 0004 / 0008 / 000C / 0010

The BRC[0:3] registers control the AHB arbiter bandwidth allocation scheme. Table 55 shows how the channels are assigned in the four registers. Table 56 shows the bit definition, or format, for each channel, using data bits [07:00] as the example.

Register name	[31:24]	[23:16]	[15:08]	[07:00]
BRC0	Channel 0	Channel 1	Channel 2	Channel 3
BRC1	Channel 4	Channel 5	Channel 6	Channel 7
BRC2	Channel 8	Channel 9	Channel 10	Channel 11
BRC3	Channel 12	Channel 13	Channel 14	Channel 15

Table 55: BRC channel assignment



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D07	R/W	CEB	0x0	**Channel enable bit** 0 Disable 1 Enable
D06	N/A	Reserved	N/A	N/A

Table 56: BRC0, BRC1, BRC2, BRC3 register

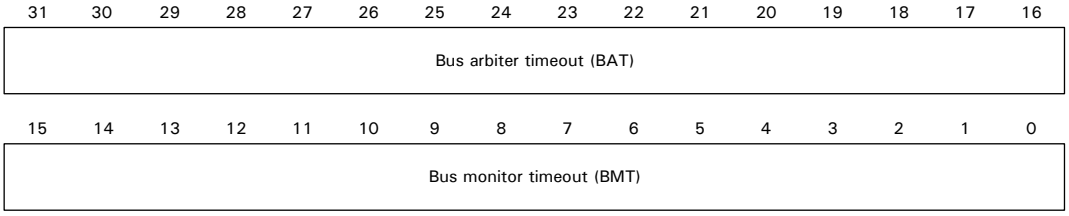
Bits	Access	Mnemonic	Reset	Description
D05:04	R/W	BRF	0x0	**Bandwidth reduction field** 00 100% 01 75% 10 50% 11 25% Programs the weight for each AHB bus master. Used to limit the round robin scheduler.
D03:00	R/W	HMSTR	0x0	**hmaster** Program a particular AHB bus master number here. Note that a particular master can be programmed to more than one channel.

Table 56: BRC0, BRC1, BRC2, BRC3 register

AHB Bus Arbiter Timeout Period/AHB Bus Monitor Timeout Period register

Address: A090 0014

The AHB Bus Arbiter Timeout Period and AHB Bus Monitor Timeout Period register configures the AHB bus arbiter timeout period and the AHB bus monitor timeout period.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:16	R/W	BAT	0xFFFF	**AHB bus arbiter timeout period** Detects system malfunction. The unit is one `hclk` period.
D15:00	R/W	BMT	0xFFFF	**AHB bus monitor timeout period** Detects an unresponsive slave. The unit is one `hclk` period.

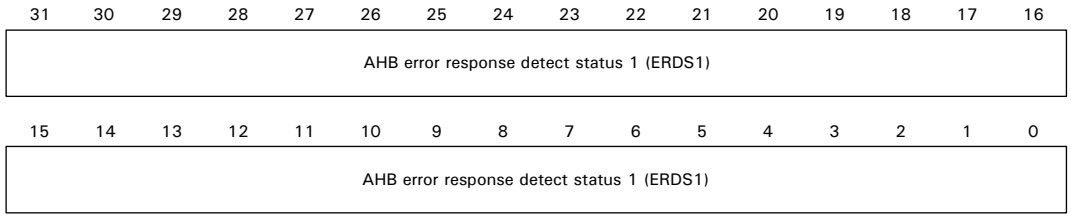
Table 57: AHB Bus Arbiter/Monitor Timeout Period register

AHB Error Status 1

Address: A090 0018

The AHB Error Status 1 register records the `haddr[31:0]` value present when any AHB error is found.

Note: This value is not reset on powerup, but is reset on a CPU read.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:00	RR	ERDS1	Not reset	**AHB error response detect status 1** The `haddr[31:0]` value recorded during a slave error response.

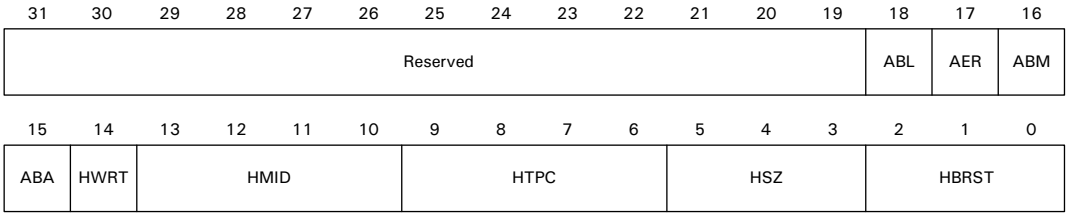
Table 58: AHB Error Status 1 register

AHB Error Status 2

Address: A090 001C

The AHB Error Status 2 register records AHB master and slave values present when any AHB error is found. The register also records which error condition was triggered.

Note: This value is not reset on powerup, but is reset on a CPU read.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:19	N/A	Reserved	N/A	N/A
D18	RR	ABL	Not reset	**AHB burst length** Is set when an AHB transaction burst length greater than AHB Max Burst Length is detected.
D17	RR	AER	Not reset	**AHB error response** Is set when an AHB slave error response is found.
D16	RR	ABM	Not reset	**AHB bus monitor** Is set when the AHB bus monitor timeout period is exceeded.
D15	RR	ABA	Not reset	**AHB bus arbiter** Is set when the AHB bus arbiter timeout period is exceeded.
D14	RR	HWRT	Not reset	**hwrite** 0 Read 1 Write Transaction type.

Table 59: AHB Error Status 2 register

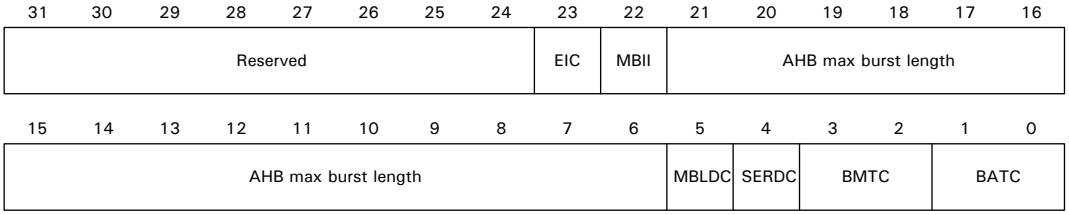
Bits	Access	Mnemonic	Reset	Description
D13:10	RR	HMID	Not reset	**hmaster [3:0]** Initiating master identifier. SeeTable 50 on page 129.
D09:06	RR	HTPC	Not reset	**hprot[3:0]** Transaction protection code: **hprot[3]** 0 Not cacheable 1 Cacheable **hprot[2]** 0 Not bufferable 1 Bufferable **hprot[1]** 0 User access 1 Privileged access **hprot[0]** 0 Opcode fetch 1 Data access
D05:03	RR	HSZ	Not reset	**hsize[2:0]** Transaction size: 000 8 bits 001 16 bits 010 32 bits
D02:00	RR	HBRST	Not reset	**hburst[2:0]** Transaction burst type: 000 Single transfer 001 Incrementing transfer of unspecified length 010 4-beat wrapping burst 011 4-beat incrementing burst 100 8-beat wrapping burst 101 8-beat incrementing burst 110 16-beat wrapping burst 111 16-beat incrementing burst

Table 59: AHB Error Status 2 register

AHB Error Monitoring Configuration register

Address: A090 0020

The AHB Error Monitoring Configuration register configures the AHB error monitoring settings.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:24	N/A	Reserved	N/A	N/A
D23	R/W	EIC	0x0	**AHB error interrupt clear** Write a 1, then a 0 in this bit to clear the AHB error interrupt.
D22	R	MBII	0x0	**AHB max burst INCR ignore** 0 Include INCR type when counting burst length 1 Ignore INCR type when counting burst length
D21:06	R/W	MBL	0x8	**AHB max burst length** Maximum number of bursts allowed in a single transfer.
D05	R/W	MBLDC	0x0	**AHB max burst length detect config** 0 Record error only 1 Generate IRQ
D04	R/W	SERDC	0x0	**AHB slave error response detect config** 0 Record error only 1 Generate IRQ

Table 60: AHB Error Monitoring Configuration register

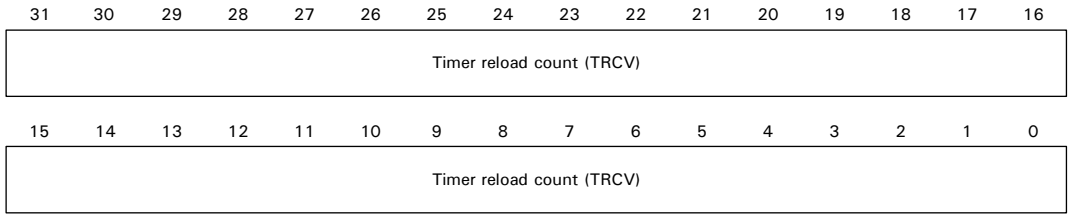
Bits	Access	Mnemonic	Reset	Description
D03:02	R/W	BMTC	0x0	**AHB bus monitor timeout config** 00 Record error only 01 Generate IRQ 10 Generate reset 11 Reserved
D01:00	R/W	BATC	0x0	**AHB bus arbiter timeout config** 00 Record error only 01 Generate IRQ 10 Generate reset 11 Reserved

Table 60: AHB Error Monitoring Configuration register

Timer 0–15 Reload Count registers

Address: A090 0044 (Timer 0) / 0048 / 004C / 0050 / 0054 / 0058 / 005C / 0060 / 0064 / 0068 / 006C / 0070 / 0074 / 0078 / 007C / 0080 (Timer 15)

The Timer Reload registers hold the up/down reload value.



Register bit assignment

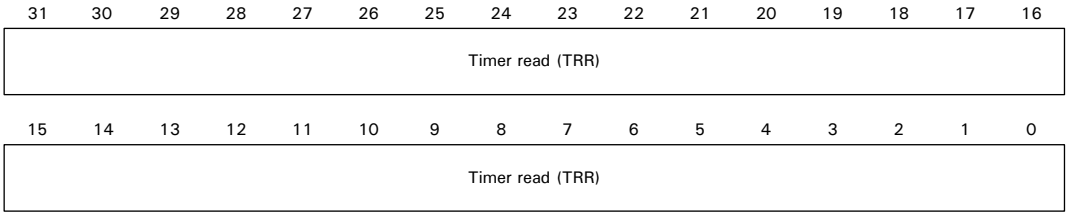
Bits	Access	Mnemonic	Reset	Description
D31:00	R/W	TRCV	0x0	**Timer Reload Count register value** Value loaded into the Timer register after the timer is enabled and after the terminal count has been reached, if the reload enable bit in the corresponding Timer Control register is set.

Table 61: Timer Reload Count register

Timer 0–15 Read register

Address: A090 0084 / 0088 / 008C / 0090 / 0094 / 0098 / 009C / 00A0 / 00A4 / 00A8 / 00AC / 00B0 / 00B4 / 00B8 / 00BC / 00C0

The Timer Read registers read the current state of each Timer register.



Register bit assignment

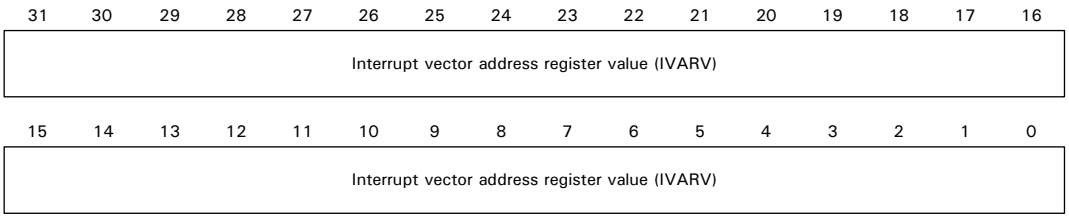
Bits	Access	Mnemonic	Reset	Description
D31:00	R	TRR	0x0	**Timer Read register** Reads the current state of each counter in a register.

Table 62: Timer Read register

Interrupt Vector Address Register Level 0–31

Address: A090 00C4 / 00C8 / 00CC / 00D0 / 00D4 / 00D8 / 00DC / 00E0 / 00E4 / 00E8 / 00EC / 00F0 / 00F4 / 00F8 / 00FC / 0100 / 0104 / 0108 / 010C / 0110 / 0114 / 0118 / 011C / 0120 / 0124 / 0128 / 012C / 0130 / 0134 / 0138 / 013C / 0140

The Interrupt Vector Address register configures the interrupt vector address for each interrupt level source. There are 32 levels.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:00	R/W	IVARV	0x0	**Interrupt Vector Address register value** Provides the interrupt vector address for the specified interrupt level.

Table 63: Interrupt vector address register

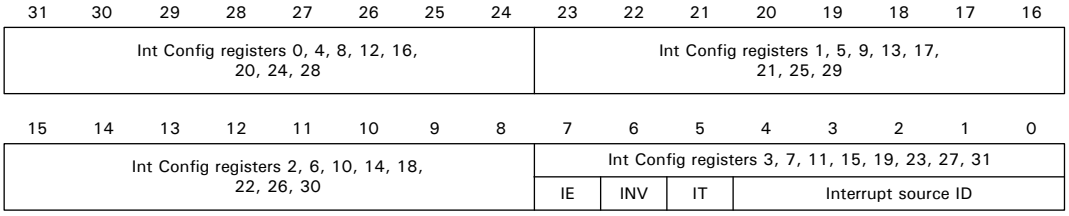
Int (Interrupt) Config (Configuration) registers (0–31)

Address: A090 0144 / 0148 / 014C / 0150 / 0154 / 0158 / 015C / 0160

Each Int Config register is 8 bits in length, and programs each interrupt configuration for each priority level. Table 64 shows how the 32 individual 8-byte registers are mapped in the eight 32-bit registers. Table 65 shows how the bits are assigned in each register, using data bits [07:00] as the example.

Register	[31:24]	[23:16]	[15:08]	[07:00]
A090 0144	Int Config 0	Int Config 1	Int Config 2	Int Config 3
A090 0148	Int Config 4	Int Config 5	Int Config 6	Int Config 7
A090 014C	Int Config 8	Int Config 9	Int Config 10	Int Config 11
A090 0150	Int Config 12	Int Config 13	Int Config14	Int Config 15
A090 0154	Int Config 16	Int Config 17	Int Config 18	Int Config 19
A090 0158	Int Config 20	Int Config 21	Int Config 22	Int Config 23
A090 015C	Int Config 24	Int Config 25	Int Config 26	Int Config 27
A090 0160	Int Config 28	Int Config 29	Int Config 30	Int Config 31

Table 64: Interrupt configuration register address mapping



Register bit assignment

Bits	Access	Mnemonic	Reset	Definition
D07	R/W	IE	0x0	**Interrupt enable** 0 Interrupt is disabled 1 Interrupt is enabled
D06	R	INV	0x0	**Invert** 0 Do not invert the level of the interrupt source. 1 Invert the level of the interrupt source.
D05	R/W	IT	0x0	**Interrupt type** 0 IRQ 1 FIQ
D04:00	R/W	ISD	0x0–0x1F	**Interrupt source ID** Assign an interrupt ID to each priority level. See "Interrupt sources," beginning on page 135, for the list of interrupt ID numbers.

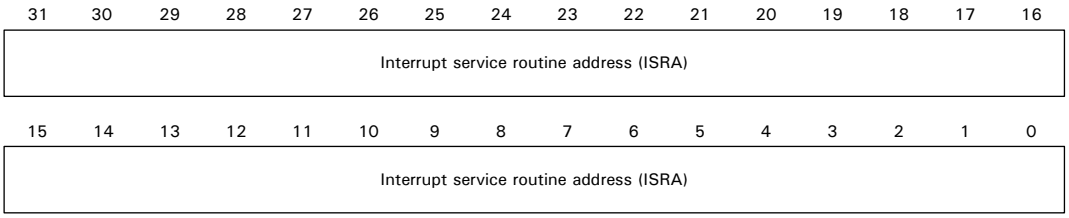
Table 65: Int Config register

ISRADDR register

Address: A090 0164

The ISRADDR register provides the current ISRADDR value.

The Interrupt Vector Address register for the FIQ interrupt must be assigned a unique value. If this unique address is seen by the IRQ service routine, software must read the ISRADDR register again. The correct IRQ interrupt service routine address is read the second time.



Register bit assignment

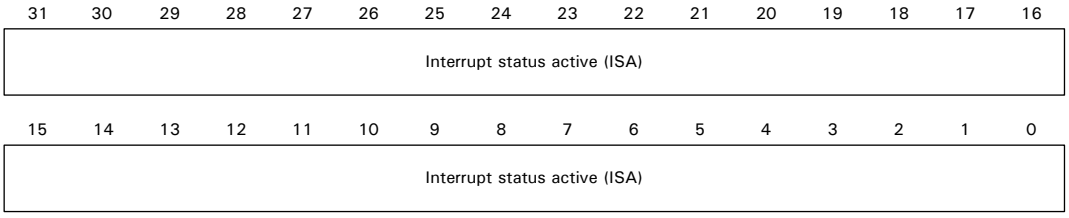
Bits	Access	Mnemonic	Reset	Description
D31:00	R/W	ISRA	0x0	**Interrupt service routine address** ■ A read to this register updates the priority logic block, and masks the current and any lower priority interrupt requests. ■ A write of any value to this register clears the mask, to allow lower priority interrupts to become active.

Table 66: ISRADDR register

Interrupt Status Active

Address: A090 0168

The Interrupt Status Active register shows the current interrupt request.



Register bit assignment

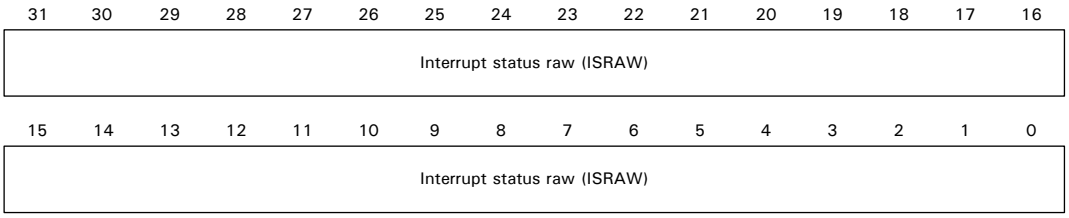
Bits	Access	Mnemonic	Reset	Description
D31:00	R	ISA	0x0	**Interrupt status active** Provides the status of all active, enabled interrupt request levels, where bit 0 is for the interrupt assigned to level 0, bit 1 is for the interrupt assigned to level 1, and so on through bit 31 for the interrupt assigned to level 31.

Table 67: Interrupt Status Active register

Interrupt Status Raw

Address: A090 016C

The Interrupt Status Raw register shows all current interrupt requests.



Register bit assignment

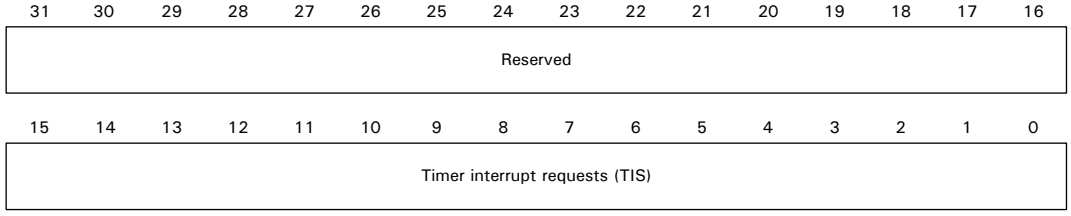
Bits	Access	Mnemonic	Reset	Description
D31:00	R	ISRAW	0x0	**Interrupt status raw** Provides the status of all active, enabled, and disabled, interrupt request levels, where bit 0 is for the interrupt assigned to level 0, bit 1 is for the interrupt assigned to level 1, and so on through bit 31 for the interrupt assigned to level 31.

Table 68: Interrupt Status Raw register

Timer Interrupt Status register

Address: A090 0170

The Timer Interrupt Status register shows all current timer interrupt requests.



Register bit assignment

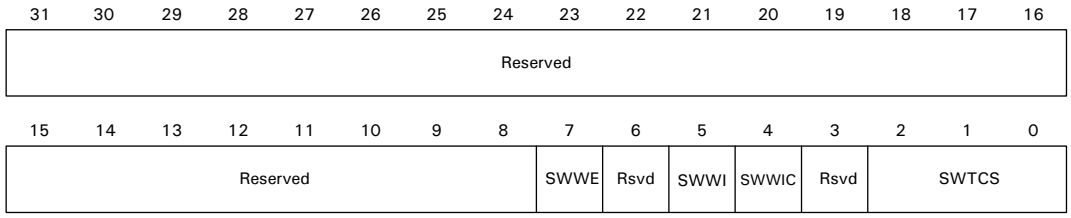
Bits	Access	Mnemonic	Reset	Description
D31:16	N/A	Reserved	N/A	N/A
D15:00	R	TIS	0x0	**Timer interrupt requests, timer 15–timer 0** 0 Inactive 1 Active

Table 69: Timer Interrupt Status register

Software Watchdog Configuration register

Address: A090 0174

The Software Watchdog Configuration register configures the software watchdog timer operation.



Register bit assignment

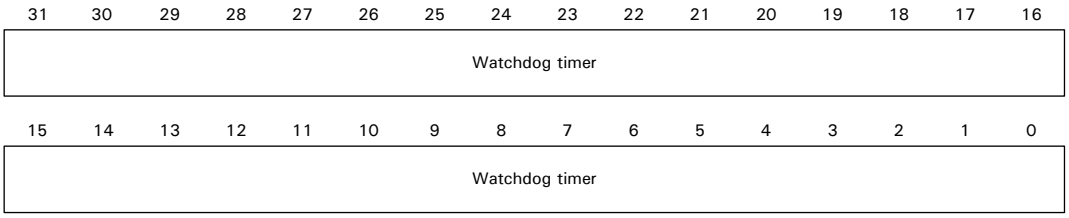
Bits	Access	Mnemonic	Reset	Description
D31:08	N/A	Reserved	N/A	N/A
D07	R/W	SWWE	0x0	**Software watchdog enable** 0 Software watchdog disabled 1 Software watchdog enabled. Once this is set, it cannot be cleared.
D06	N/A	Reserved	N/A	N/A
D05	R/W	SWWI	0x0	**Software watchdog interrupt clear** Write a 1, then a 0 to this bit to clear the software watchdog interrupt.
D04	R/W	SWWIC	0x0	**Software watchdog interrupt response** 0 Generate an interrupt 1 Generate the reset
D03	N/A	Reserved	N/A	**N/A**
D02:00	R/W	SWTCS	0x0	**Software watchdog timer clock select** 000 CPU clock / 2 001 CPU clock / 4 010 CPU clock / 8 011 CPU clock / 16 100 CPU clock / 32 101 CPU clock / 64 110 Reserved 111 Reserved

Table 70: Software Watchdog Configuration register

Software Watchdog Timer register

Address: A090 0178

The Software Watchdog Timer register services the watchdog timer.



Register bit assignment

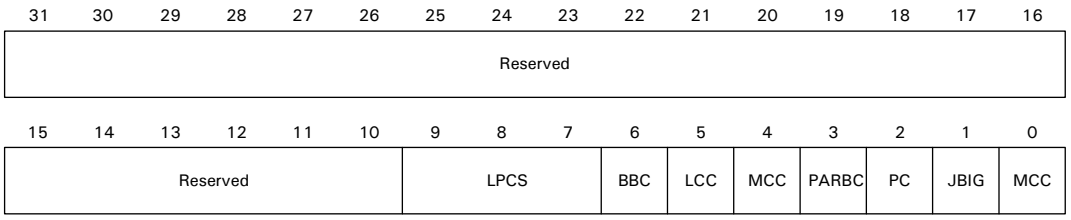
Bits	Access	Mnemonic	Reset	Description
D31:00	R/W	WT	0x0	**Watchdog timer** ■ A *read* to this register gives the current value of the watchdog timer, but will not change the contents. ■ A *write* to the register changes the contents based on the write data value.

Table 71: Software Watchdog Timer register

Clock Configuration register

Address: A090 017C

The Clock Configuration register enables and disables clocks to each module on the AHB bus.



Register bit assignment

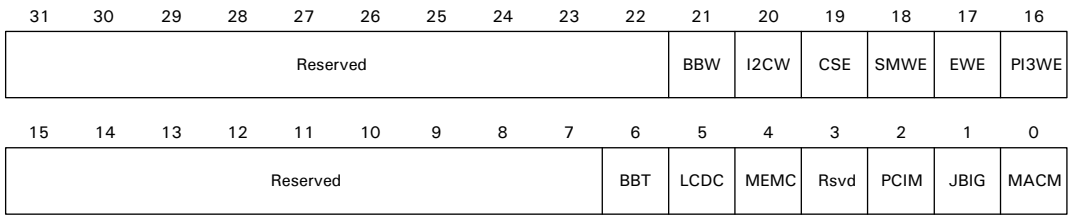
Bits	Access	Mnemonic	Reset	Description
D31:10	N/A	Reserved	N/A	N/A
D09:07	R/W	LPCS	0x0	**LCD panel clock select** 000 AHB clock 001 AHB clock / 2 010 AHB clock / 4 011 AHB clock / 8 1xx LCD clock provided by external clock
D06	R/W	BBC	0x1	**BBus** 0 Clock disabled 1 Clock enabled
D05	R/W	LCC	0x1	**LCD controller** 0 Clock disabled 1 Clock enabled
D04	R/W	MCC	0x1	**Memory controller** 0 Clock disabled 1 Clock enabled
D03	R/W	PARBC	0x1	**PCI arbiter** 0 Clock disabled 1 Clock enabled
D02	R/W	PC	0x1	**PCI** 0 Clock disabled 1 Clock enabled
D01	R/W	JBIGC	0x1	**JBIG** 0 Clock disabled 1 Clock enabled
D00	R/W	MACC	0x1	**Ethernet MAC** 0 Clock disabled 1 Clock enabled

Table 72: Clock Configuration register

Reset and Sleep Control register

Address: A090 0180

The Reset and Sleep Control register resets each module on the AHB bus. To use sleep mode, the CPU must reset and stop the clocks to all modules not used to wake up the CPU. The memory controller must be reset and then re-enabled. The code that resets the memory controller must be loaded into instruction cache first. The last step is to set the CSE bit (D19) in the Reset and Sleep Control register.



Register bit assignment

Bits	Access	Mnemonic	Reset	Definition
D31:22	N/A	Reserved	N/A	N/A
D21	R/W	BBW	0x0	**BBus aggregate interrupt wakeup enable** 0 Do not wake up on a BBus aggregate interrupt. 1 Wake up on a BBus aggregate interrupt.
D20	R/W	I2CW	0x0	**I2C interrupt wake up enable** 0 Do not wake up on an I2C interrupt. 1 Wake up on an I2C interrupt.
D19	R/W	CSE	0x0	**CPU sleep enable** System software writes a 1 to this bit to reset and stop the clock to the CPU. Note that software is responsible for stopping the clocks to all other modules before setting this bit. This bit must be cleared after the CPU is woken up, before reentering the sleep state.

Table 73: Reset and Sleep Control register

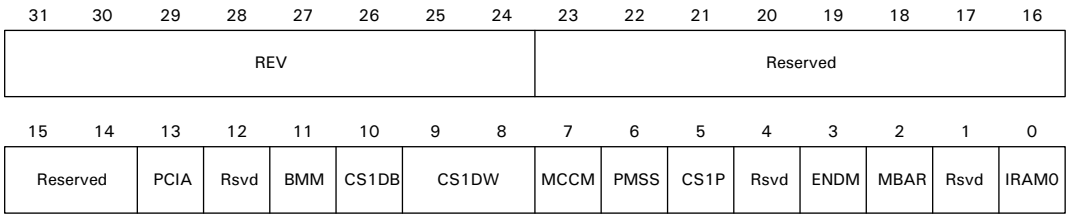
Bits	Access	Mnemonic	Reset	Definition
D18	R/W	SMWE	0x0	**Serial character match wake-up enable** 0 Do not wake up on receipt of a character match by the serial module. 1 Wake up on receipt of a character match by the serial module.
D17	R/W	EWE	0x0	**Ethernet wake-up enable** 0 Do not wake up on receipt of an Ethernet packet. 1 Wake up on receipt of an Ethernet packet.
D16	R/W	PI3WE	0x0	**PCI interrupt 3 wake-up enable** 0 Do not wake up on PCI interrupt 3 input signal. 1 Wake up on active low PCI interrupt 3 input signal.
D15:07	N/A	Reserved	N/A	N/A
D06	R/W	BBT	0x1	**BBus top** 0 Module reset 1 Module enabled
D05	R/W	LCDC	0x1	**LCD controller** 0 Module reset 1 Module enabled
D04	R/W	MEMC	0x1	**Memory controller** 0 Module reset 1 Module enabled
D03	N/A	Reserved	N/A	N/A
D02	R/W	PCIM	0x1	**PCI module** 0 Module reset 1 Module enabled
D01	R/W	JBIGM	0x1	**JBIG** 0 Module reset 1 Module enabled
D00	R/W	MACM	0x1	**Ethernet MAC** 0 Module reset 1 Module enabled

Table 73: Reset and Sleep Control register

Miscellaneous System Configuration and Status register

Address: A090 0184

The Miscellaneous System Configuration and Status register configures miscellaneous system configuration bits.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:24	R	REV	0x0	**Revision** Indicates the NS9775 hardware identification and revision.
D23:14	N/A	Reserved	N/A	N/A
D13	R	PCIA	0x1	**PCI arbiter configuration** 0 External PCI arbiter 1 Internal PCI arbiter
D12	N/A	Reserved	N/A	N/A
D11	R	BMM	HW strap reset_done	**Bootup memory mode** 0 Boot from SDRAM using SPI serial EEPROM 1 Boot from Flash/ROM on memory chip select 1 Status only; indicates the bootup process.
D10	R	CS1DB	HW strap print_out	**Chip select 1 data byte lane configuration HW strap setting** Status bit indicating the hardware strap setting of external memory chip select 1 byte lane/write enable signal configuration. This configuration can be changed by writing to the appropriate control register in the memory controller.

Table 74: Miscellaneous System Configuration and Status register

Bits	Access	Mnemonic	Reset	Description
D09:08	R	CS1DW	HW strap bp_stat[3], bp_stat[2]	**Chip select 1 data width HW strap setting** 00 8 bits 01 16 bits 10 32 bits 11 Reserved Status bits indicating the hardware strap setting of external memory chip select 1 data width. The data width can be changed by writing to the appropriate control register in the memory controller.
D07	R/W	MCCM	HW strap bp_stat[1]	**Memory controller clocking mode HW strap setting** Status bit indicating the hardware strap setting of external memory controller clocking mode. 0 Command delayed mode. Commands are launched on a 90-degree phase-shifted AHB clock, and AHB clock is routed to the external dynamic memory. This option must be used. 1 Clock delayed mode. Reserved for future use.
D06	R	PMSS	HW strap bp_stat[0]	**PCI mode HW strap setting** 0 Card bus mode 1 PCI mode Status bit indicating the hardware strap setting for PCI.
D05	R	CS1P	HW strap gpio[49]	**Chip select 1 polarity HW strap setting** Status bit indicating the hardware strap setting of external memory chip select 1 polarity. The polarity can be changed by writing to the appropriate control registers in the memory controller.
D04	R	Reserved	N/A	N/A
D03	R/W	ENDM	HW strap gpio[44]	**Endian mode** 0 Little endian mode 1 Big endian mode

Table 74: Miscellaneous System Configuration and Status register

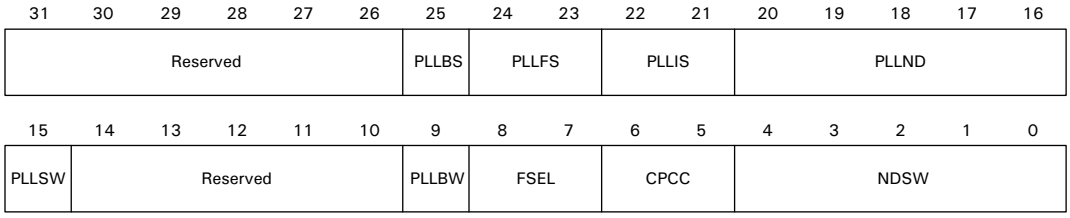
Bits	Access	Mnemonic	Reset	Description
D02	R/W	MBAR	0x0	**Misaligned bus address response mode** 0 Allow misaligned bus addresses 1 Generate an error response when a misaligned bus address is found; that is, when `haddr` bits 1 or 0 are not level 0.
D01	N/A	Reserved	N/A	N/A
D00	R/W	IRAM0	0x0	**Internal register access mode bit 0** 0 Allow access to internal registers using PRIVILEGED mode only 1 Allow access to internal registers using PRIVILEGED or USER mode.

Table 74: Miscellaneous System Configuration and Status register

PLL Configuration register

Address: A090 0188

The PLL Configuration register configures the PLL.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:26	N/A	Reserved	N/A	N/A
D25	R	PLLBS	HW strap gpio[19]	**PLL bypass status** Status register to determine the powerup strapping settings or the new settings as changed by software.

Table 75: PLL Configuration register

Bits	Access	Mnemonic	Reset	Description
D24:23	R	PLLFS	HW strap gpio[2], gpio[0]	**PLL FS status [1:0]** Status register to determine the powerup strapping settings or the new settings as changed by software.
D22:21	R	PLLIS	HW strap gpio[24], gpio[22]	**PLL IS status[1:0]** Status register to determine the powerup strapping settings or the new settings as changed by software.
D20:16	R	PLLND	HW strap gpio[17], gpio[12], gpio[10], gpio[8], gpio[4]	**PLL ND status[4:0]** Status register to determine the powerup strapping settings or the new settings as changed by software.
D15	W	PLLSW	0x0	**PLL SW change** Write a 1 to this bit to change the PLL settings as defined in bits D09:00. **Note:** The system is held in reset until the PLL is locked and settled. If the PLL bypass SW bit is set (D09), the PLL setting change and reset is immediate. If the PLL bypass SW bit is not set, the PLL setting change and reset take 4ms to complete.
D14:10	N/A	Reserved	N/A	N/A
D09	R/W	PLLBW	0x0	**PLL bypass SW** 0 PLL operation 1 PLL bypass; use the input reference clock
D08:07	R/W	FSEL	0x0	**PLL frequency select (FS) [1:0]** **PLL** **Output divider value** 00 Divide by 1 01 Divide by 2 10 Divide by 4 11 Divide by 8

Table 75: PLL Configuration register

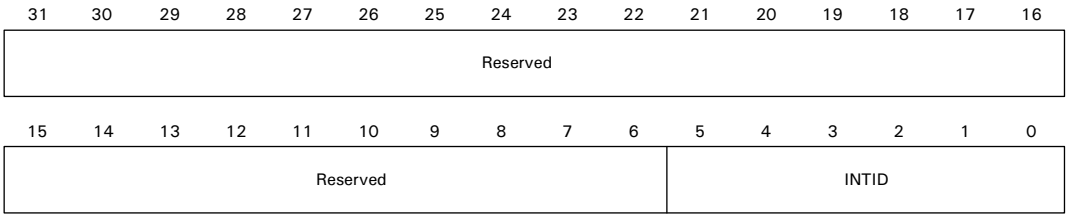
Bits	Access	Mnemonic	Reset	Description
D06:05	R/W	CPCC	0x3	**PLL charge pump current control (IS) [1:0]** Recommended settings determined by ND, as follows: **IS** **ND** 00 0–3 01 4–7 10 8–15 11 16–31
D04:00	R/W	NDSW	0x1A	**PLL ND SW [4:0]** PLL multiplier (ND + 1).

Table 75: PLL Configuration register

Active Interrupt Level Status register

Address: A090 018C

The Active Interrupt Level Status register shows the current active interrupt level.



Register bit assignment

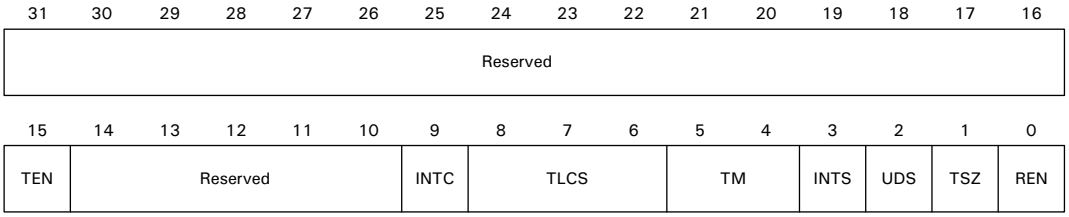
Bits	Access	Mnemonic	Reset	Description
D31:06	N/A	Reserved	N/A	N/A
D05:00	R	INTID	0x0	**Interrupt** The level of the current active interrupt.

Table 76: Active Interrupt Level Status register

Timer 0–15 Control registers

Address: A090 0190 / 0194 / 0198 / 019C / 01A0 / 01A4 / 01A8 / 01AC / 01B0 / 01B4 / 01B8 / 01BC / 01C0 / 01C4 / 01C8 / 01CC

Use the Timer Control registers to select the source clock frequency, as well as other attributes, for each general purpose timer/counter.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
31:16	N/A	Reserved	N/A	N/A
D15	R/W	TEN	0x0	**Timer enable** 0 Timer is disabled 1 Timer is enabled
D14:10	N/A	Reserved	N/A	N/A
D09	R/W	INTC	0x0	**Interrupt clear** Clears the timer interrupt. System software must write a 1, then a 0 to this location to clear the interrupt. If the timer is programmed to halt on terminal count (that is, REN is clear), the software must disable the timer by setting TEN to 0 before clearing the interrupt by writing a 1 and then a 0 to INTC.

Table 77: Timer Control register

Bits	Access	Mnemonic	Reset	Description
D08:06	R/W	TLCS	0x0	**Timer clock select** 000 CPU clock (must be used if this is the high word of two concatenated timers) 001 CPU clock / 2 010 CPU clock / 4 011 CPU clock / 8 100 CPU clock / 16 101 CPU clock / 32 110 CPU clock / 64 111 External pulse event **Notes:** ■ Counting external pulse events, the frequency must be less than one-half the CPU clock frequency. ■ For TLCS settings 000 – 110, the terminal count can be output using GPIO. The terminal count pulse width will be one CPU clock cycle, regardless of the TLCS setting.
D05:04	R/W	TM	0x0	**Timer mode** 00 Internal timer or external event 01 External low-level, gated timer 10 External high-level, gated timer 11 Concatenate the lower timer. Not applicable on timer 0. **Note:** When either external gated timer option is selected, the timer clock select bits (08:06) determine the frequency.
D03	R/W	INTS	0x0	**Interrupt select** 0 Interrupt disable 1 Generate IRQ
D02	R/W	UDS	0x0	**Up/down select** 0 Up counter 1 Down counter **Note:** When configured as an up counter, the terminal count is 0xFFFF_FFFF. When configured as a down counter, the terminal count is 0x0000_0000.

Table 77: Timer Control register

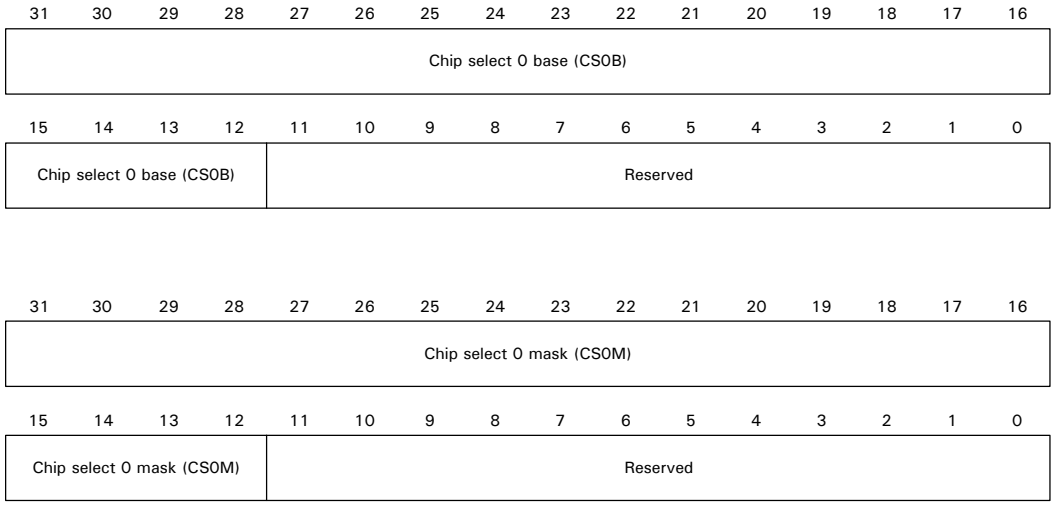
Bits	Access	Mnemonic	Reset	Description
D01	R/W	TSZ	0x0	**32- or 16-bit timer** 0 16-bit timer 1 32-bit timer
D00	R/W	REN	0x0	**Reload enable** 0 Halt at terminal count. The timer must be disabled, then enabled to reload the timer when the terminal count is reached. The interrupt select (INTS) bit must be cleared during the interrupt service routine when this mode is selected. 1 Reload and resume count at terminal count.

Table 77: Timer Control register

System Memory Chip Select 0 Dynamic Memory Base and Mask registers

Address: A090 01D0 / 01D4

These control registers set the base and mask for system memory chip select 1, with a minimum size of 4K. The powerup default settings produce a memory range of 0x0000 0000 – 0x0FFF FFFF.



Register bit assignment

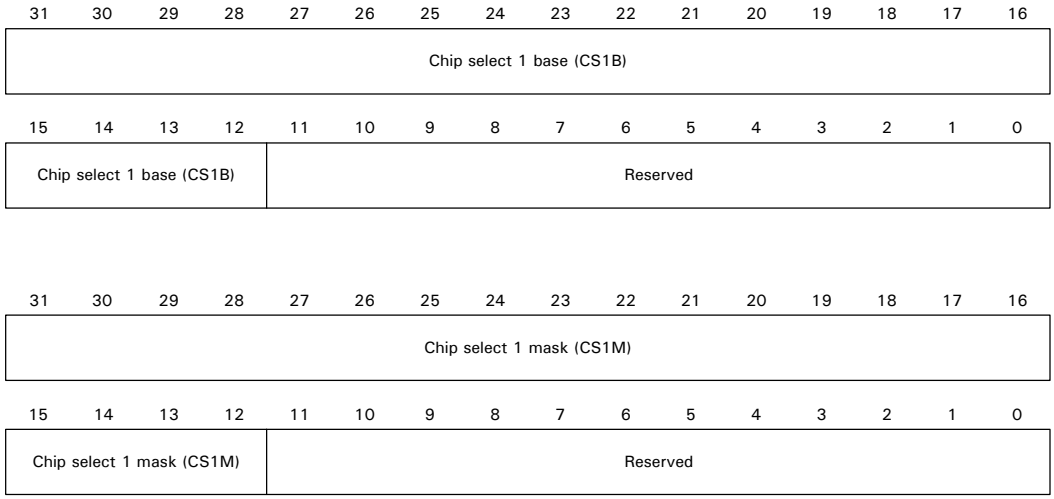
Bits	Access	Mnemonic	Reset	Description
D31:12	R/W	CS0B	0x00000	**Chip select 0 base** Base address for chip select 0 (dynamic).
D11:00	N/A	Reserved	N/A	N/A
D31:12	R/W	CS0M	0xF0000	**Chip select 0 mask** Mask or size for chip select 0 (dynamic).
D11:00	N/A	Reserved	N/A	N/A

Table 78: System Memory Chip Select 0 Dynamic Memory Base & Mask registers

System Memory Chip Select 1 Dynamic Memory Base and Mask registers

Address: A090 01D8 / 01DC

These control registers set the base and mask for system memory chip select 1, with a minimum size of 4K. The powerup default settings produce a memory range of 0x1000 0000 – 0x1FFF FFFF.



Register bit assignment

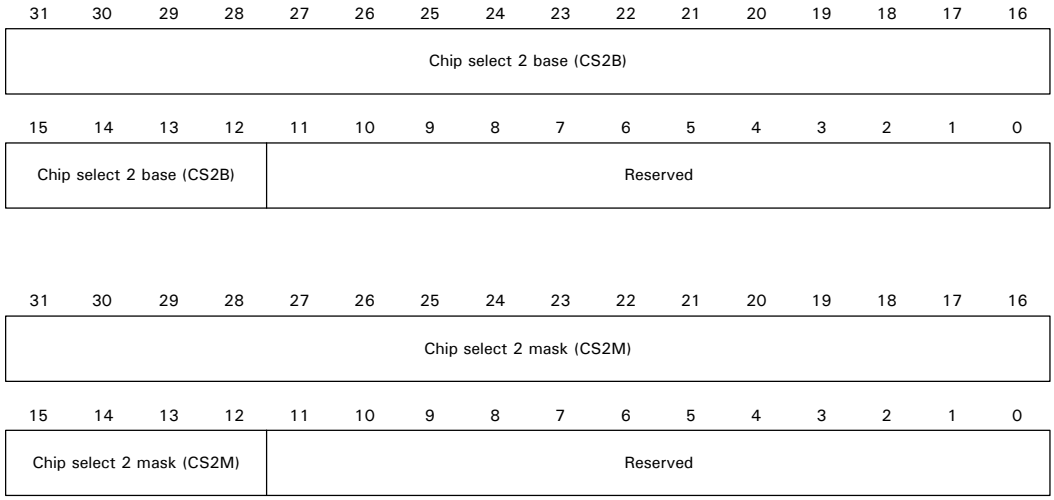
Bits	Access	Mnemonic	Reset	Description
D31:12	R/W	CS1B	0x10000	**Chip select 1 base** Base address for chip select 1 (dynamic).
D11:00	N/A	Reserved	N/A	N/A
D31:12	R/W	CS1M	0xF0000	**Chip select 1 mask** Mask or size for chip select 1 (dynamic).
D11:00	N/A	Reserved	N/A	N/A

Table 79: System Memory Chip Select 1 Dynamic Memory Base & Mask registers

System Memory Chip Select 2 Dynamic Memory Base and Mask registers

Address: A090 01E0 / 01E4

These control registers set the base and mask for system memory chip select 6, with a minimum size of 4K. The powerup default settings produce a memory range of 0x2000 0000 – 0x2FFF FFFF.



Register bit assignment

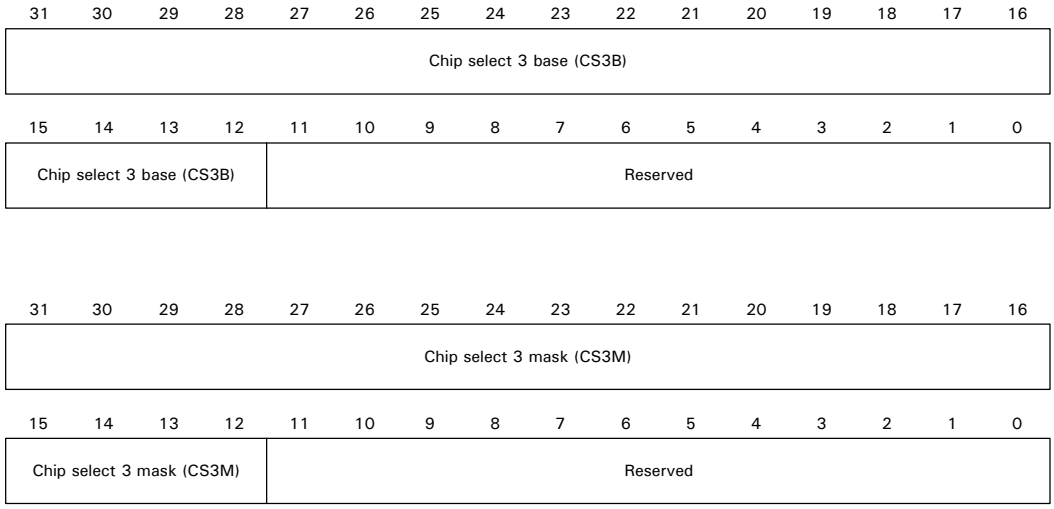
Bits	Access	Mnemonic	Reset	Description
D31:12	R/W	CS2B	0x20000	**Chip select 2 base** Base address for chip select 2 (dynamic).
D11:00	N/A	Reserved	N/A	N/A
D31:12	R/W	CS2M	0xF0000	**Chip select 2 mask** Mask or size for chip select 2 (dynamic).
D11:00	N/A	Reserved	N/A	N/A

Table 80: System Memory Chip Select 2 Dynamic Memory Base & Mask registers

System Memory Chip Select 3 Dynamic Memory Base and Mask registers

Address: A090 01E8 / 01EC

These control registers set the base and mask for system memory chip select 7, with a minimum size of 4K. The powerup default settings produce a memory range of 0x3000 0000 – 0x3FFF FFFF.



Register bit assignment

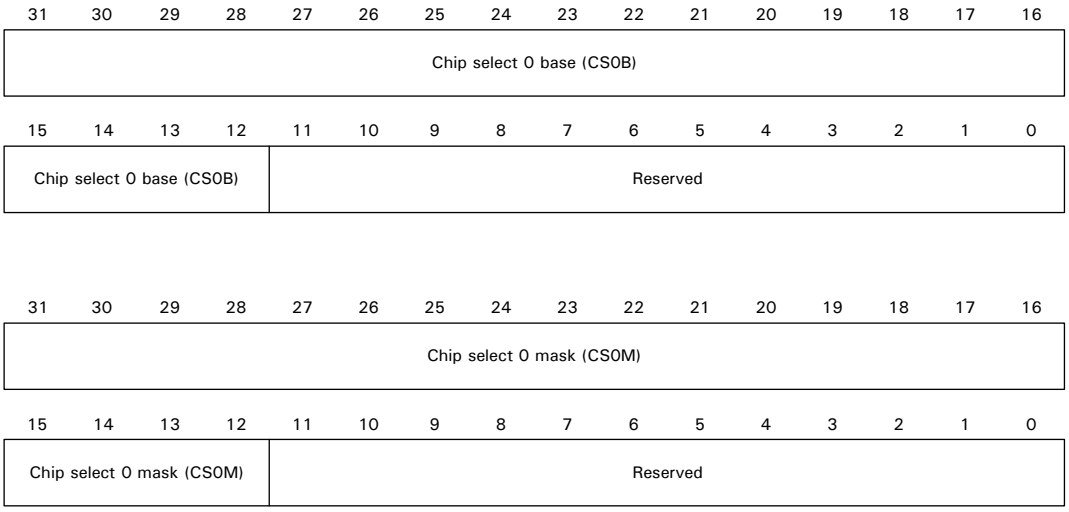
Bits	Access	Mnemonic	Reset	Description
D31:12	R/W	CS3B	0x30000	**Chip select 3 base** Base address for chip select 3 (dynamic).
D11:00	N/A	Reserved	N/A	N/A
D31:12	R/W	CS3M	0xF0000	**Chip select 3 mask** Mask or size for chip select 3 (dynamic).
D11:00	N/A	Reserved	N/A	N/A

Table 81: System Memory Chip Select 3 Dynamic Memory Base & Mask registers

System Memory Chip Select 0 Static Memory Base and Mask registers

Address: A090 01F0 / 01F4

These control registers set the base and mask for system memory chip select 0, with a minimum size of 4K. The powerup default settings produce a memory range of 0x4000 0000 – 0x4FFF FFFF.



Register bit assignment

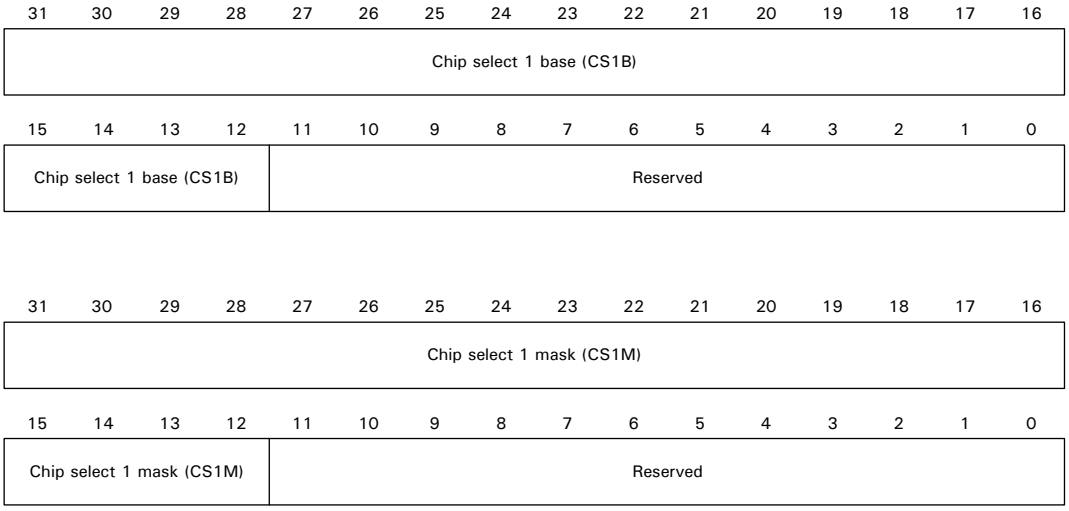
Bits	Access	Mnemonic	Reset	Description
D31:12	R/W	CS0B	0x40000	**Chip select 0 base** Base address for chip select 0 (static).
D11:00	N/A	Reserved	N/A	N/A
D31:12	R/W	CS0M	0xF0000	**Chip select 0 mask** Mask or size for chip select 0 (static).
D11:00	N/A	Reserved	N/A	N/A

Table 82: System Memory Chip Select 0 Static Memory Base & Mask registers

System Memory Chip Select 1 Static Memory Base and Mask registers

Address: A09001F8 / 01FC

These control registers set the base and mask for system memory chip select 1, with a minimum size of 4K. The powerup default settings produce a memory range of 0x5000 0000 – 0x5FFF FFFF.



Register bit assignment

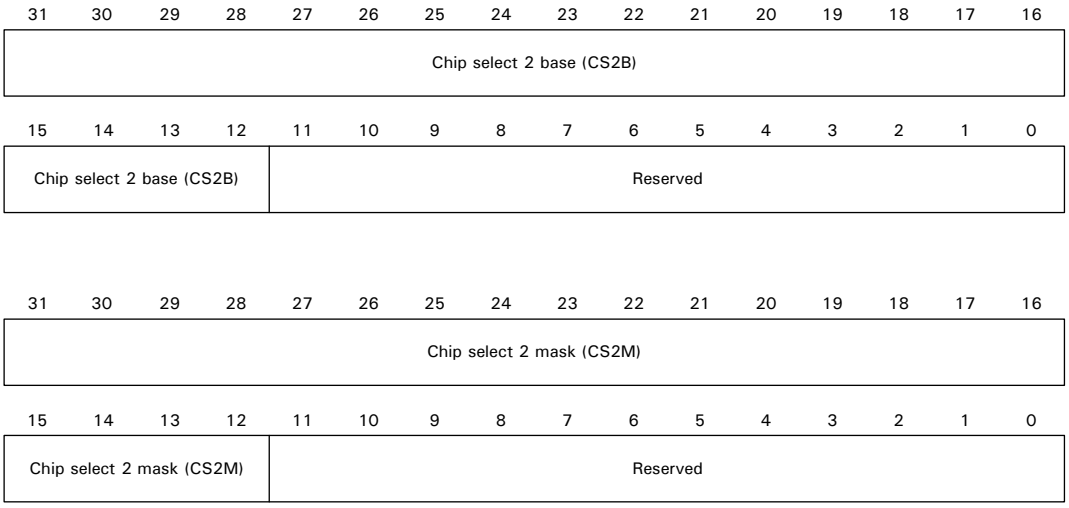
Bits	Access	Mnemonic	Reset	Description
D31:12	R/W	CS1B	0x50000	**Chip select 1 base** Base address for chip select 1 (static).
D11:00	N/A	Reserved	N/A	N/A
D31:12	R/W	CS1M	0xF0000	**Chip select 1 mask** Mask or size for the chip select 1 (static).
D11:00	N/A	Reserved	N/A	N/A

Table 83: System Memory Chip Select 1 Memory Base and Mask registers

System Memory Chip Select 2 Static Memory Base and Mask registers

Address: A090 0200 / 0204

These control registers set the base and mask for system memory chip select 2, with a minimum size of 4K. The powerup default settings produce a memory range of 0x6000 0000 – 0x6FFF FFFF.



Register bit assignment

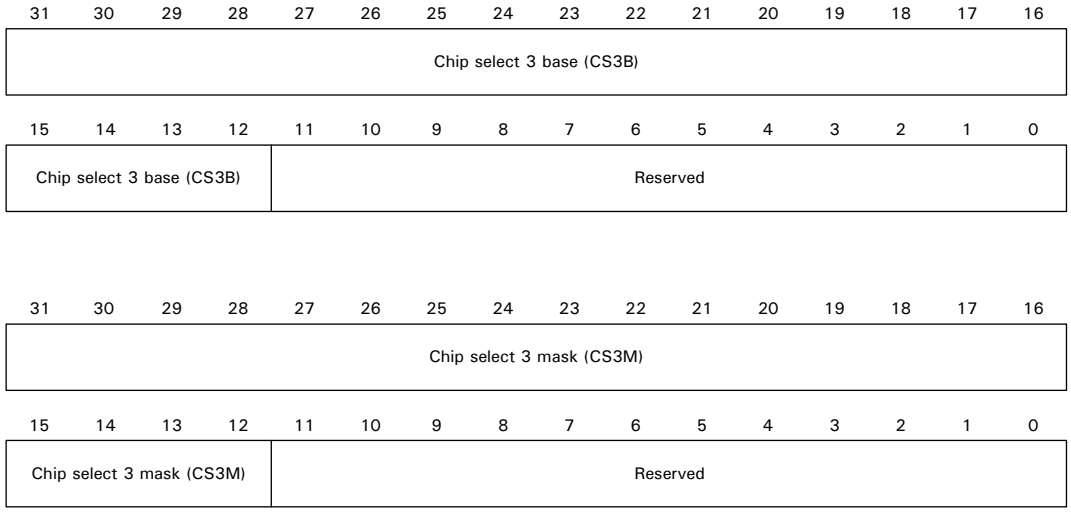
Bits	Access	Mnemonic	Reset	Description
D31:12	R/W	CS2B	0x60000	**Chip select 2 base** Base address for chip select 2 (static).
D11:00	N/A	Reserved	N/A	N/A
D31:12	R/W	CS2M	0xF0000	**Chip select 2 mask** Mask or size for chip select 2 (static).
D11:00	N/A	Reserved	N/A	N/A

Table 84: System Memory Chip Select 2 Static Memory Base & Mask registers

System Memory Chip Select 3 Static Memory Base and Mask registers

Address: A090 0208 / 020C

These control registers set the base and mask for system memory chip select 3, with a minimum size of 4K. The powerup default settings produce a memory range of 0x7000 0000 – 0x7FFF FFFF.



Register bit assignment

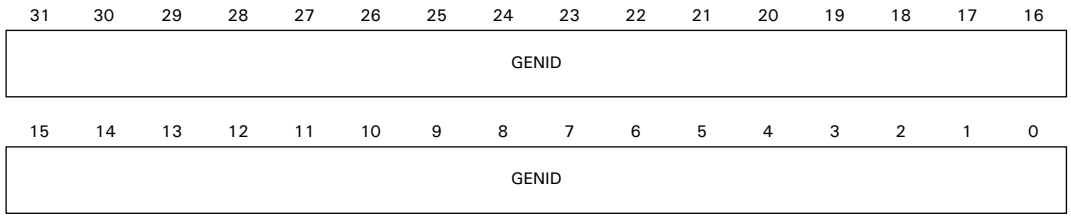
Bits	Access	Mnemonic	Reset	Description
D31:12	R/W	CS3B	0x70000	**Chip select 3 base** Base address for chip select 3 (static).
D11:00	N/A	Reserved	N/A	N/A
D31:12	R/W	CS3M	0xF0000	**Chip select 3 mask** Mask or size for chip select 3 (static).
D11:00	N/A	Reserved	N/A	N/A

Table 85: System Memory Chip Select 3 Static Memory Base & Mask registers

Gen ID register

Address: A090 0210

This register is read-only, and indicates the state of GPIO pins at powerup.



Register bit assignment

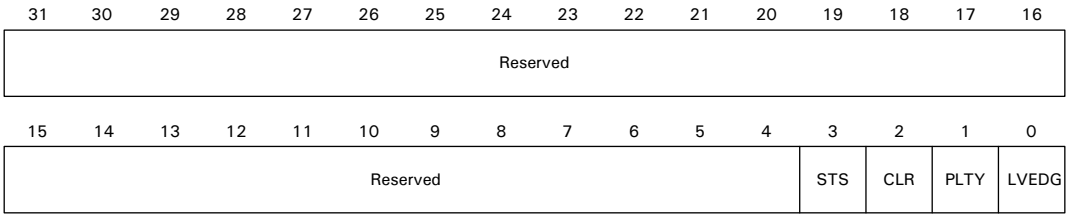
Bits	Access	Mnemonic	Reset	Description
D31:00	R	GENID	Reflects the status of the GPIO inputs at reset. The GPIO signals are listed in "Bootstrap initialization," beginning on page 139.	**GenID** General Purpose ID register

Table 86: General Purpose ID register

External Interrupt 0–3 Control register

Address: A090 0214 / 0218 / 021C / 0220

The External Interrupt Control registers control the behavior of external interrupts 0–3. The external interrupts are behind GPIO (see "GPIO MUX," beginning on page 38).



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:04	N/A	Reserved	N/A	N/A
D03	R	STS	N/A	**Status** Status of the external signal before edge detect or level conversion.
D02	R/W	CLR	0x0	**Clear** Write a 1 to this bit to clear the interrupt generated by the edge detect circuit.
D01	R/W	PLTY	0x0	**Polarity** 0 If level-sensitive, the input source is active high. If edge-sensitive, generate an interrupt on the rising edge of the external interrupt. 1 If level-sensitive, the input source is active low. The level is inverted before sending to the interrupt controller. If edge-sensitive, generate an interrupt on the falling edge of the external interrupt.
D00	R/W	LVEDG	0x0	**Level edge** 0 Level-sensitive interrupt 1 Edge-sensitive interrupt

Table 87: External Interrupt 0–3 Control register

Memory Controller

CHAPTER 5

The Multiport Memory Controller is an AMBA-compliant system-on-chip (SoC) peripheral that connects to the Advanced High-performance Bus (AHB). The remainder of this chapter refers to this controller as the *memory controller*.

Features

The memory controller provides these features:

- AMBA 32-bit AHB compliancy.
- Dynamic memory interface support including SDRAM and JEDEC low-power SDRAM.
- Asynchronous static memory device support including RAM, ROM, and Flash, with and without asynchronous page mode.
- Can operate with cached processors with copyback caches.
- Can operate with uncached processors.
- Low transaction latency.
- Read and write buffers to reduce latency and improve performance, particularly for uncached processors.
- 8-bit, 16-bit, and 32-bit wide static memory support.
- 16-bit and 32-bit wide chip select SDRAM memory support.
- Static memory features, such as:
  - Asynchronous page mode read
  - Programmable wait states
  - Bus turnaround delay
  - Output enable and write enable delays
  - Extended wait
- Power-saving modes that dynamically control SDRAM `clk_en`.
- Dynamic memory self-refresh mode supported by a power management unit (PMU) interface or by software.
- Controller supports 2K, 4K, and 8K row address synchronous memory parts; that is, typical 512 MB, 256 MB, and 16 Mb parts with 8, 16, or 32 DQ bits per device.
- A separate AHB interface to program the memory controller. This enables the memory controller registers to be situated in memory with other system peripheral registers.
- Locked AHB transaction support.

- Support for all AHB burst types.
- Little and big endian support.

Note: Synchronous static memory devices (synchronous burst mode) are not supported.

System overview

Figure 44 shows the NS9775 memory controller in a sample system.

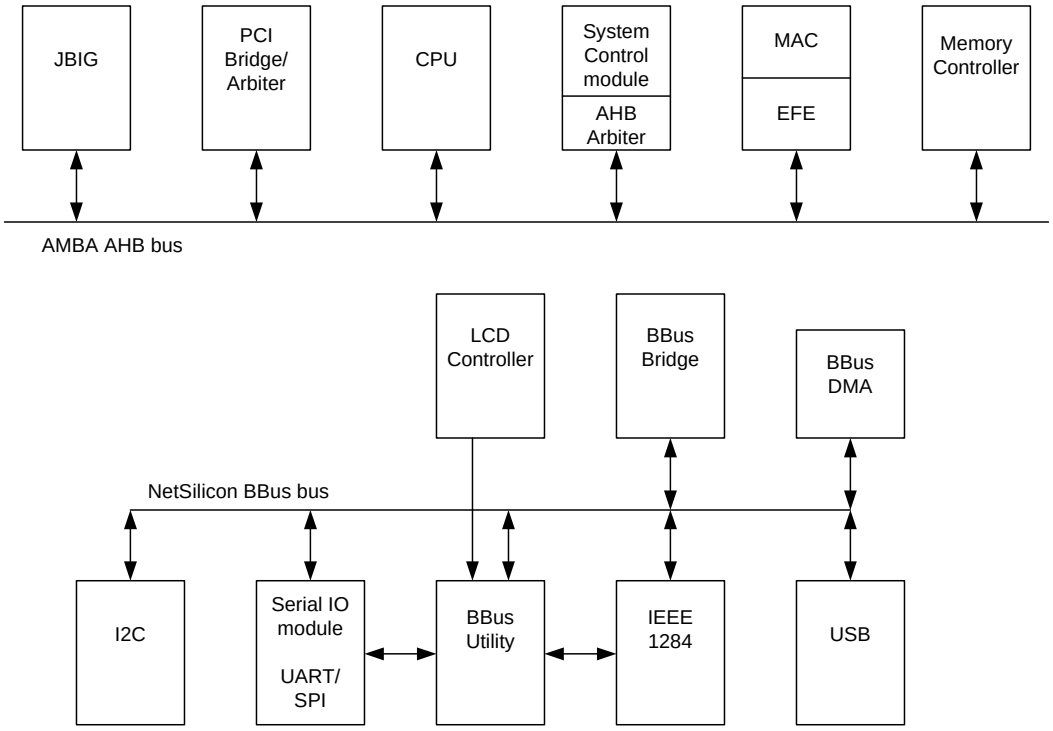


Figure 44: NS9775 sample system

Note: The largest amount of memory allowed for a single chip select is 256 MB.

Low-power operation

In many systems, the contents of the memory system have to be maintained during low-power sleep modes. NS9775 provides two features to enable this:

- Dynamic memory refresh over soft reset
- A mechanism to place the dynamic memories into self-refresh mode

Self-refresh mode can be entered as follows:

1. Set the SREFREQ bit in the Dynamic Memory Control register (see page 282).
2. Poll the SREFACK bit in the Status register (see page 280).

Note: Static memory can be accessed as normal when the SDRAM memory is in self-refresh mode.

Low-power SDRAM partial array refresh

The memory controller supports JEDEC low-power SDRAM partial array refresh. Partial array refresh can be programmed by initializing the SDRAM memory device appropriately. When the memory device is put into self-refresh mode, only the memory banks specified are refreshed. The memory banks that are not refreshed lose their data contents.

Memory map

The memory controller provides hardware support for booting from external nonvolatile memory. During booting, the nonvolatile memory must be located at address 0x00000000 in memory. When the system is booted, the SRAM or SDRAM memory can be remapped to address 0x00000000 by modifying the address map in the AHB decoder.

Power-on reset memory map

On power-on reset, memory chip select 1 is mirrored onto memory chip select 0 and chip select 4. Any transactions to memory chip select 0 or chip select 4 (or chip select 1), then, access memory chip select 1. Clearing the address mirror bit (M) in the Control register (see page 278) disables address mirroring, and memory chip select 0, chip select 4, and memory chip select 1 can be accessed as normal.

Chip select 1 memory configuration

You can configure the memory width and chip select polarity of static memory chip select 1 by using selected input signals. This allows you to boot from chip select 1.

These are the bootstrap signals:

- `boot_strap[4:3]`: Memory width select
- `gpio[49]`: Chip select polarity
- `boot_strap[0]`: `Byte lane enable_n/write_enable_n` for byte-wide devices

Example: Boot from flash, SRAM mapped after boot

The system is set up as:

- Chip select 1 is connected to the boot flash device.
- Chip select 0 is connected to the SRAM to be remapped to `0x00000000` after boot.

The boot sequence is as follows:

1. At power-on, the reset chip select 1 is mirrored into chip select 0 (and chip select 4). The following signals are configured so the nonvolatile memory device can be accessed:
   - `boot_strap[4:3]`
   - `gpio[49]`
2. When the power-on reset (`reset_n`) and AHB reset (`HRESETn`) go inactive, the processor starts booting from `0x00000000` in memory.
3. The software programs the optimum delay values in the flash memory so the boot code can run at full speed.
4. The code branches to chip select 1 so the code can continue executing from the non-remapped memory location.
5. The appropriate values are programmed into the memory controller to configure chip select 0.
6. The address mirroring is disabled by clearing the address mirror (M) field in the Control register (see page 278).
7. The ARM reset and interrupt vectors are copied from flash memory to SRAM that can then be accessed at address `0x00000000`.
8. More boot, initialization, or application code is executed.

Example: Boot from flash, SDRAM remapped after boot

The system is set up as:

- Chip select 1 is connected to the boot flash device.
- Chip select 4 is connected to the SDRAM to be remapped to `0x00000000` after boot.

The boot sequence is as follows:

1. At power-on, the reset chip select 1 is mirrored into chip select 4 (and chip select 0). The following signals are configured so the nonvolatile memory device can be accessed:
   - `boot_strap[4:3]`
   - `gpio[49]`
2. When the power-on reset (`reset_n`) and AHB reset (`HRESETn`) go inactive, the processor starts booting from `0x00000000` in memory.
3. The software programs the optimum delay values in flash memory so the boot code can run at full speed.
4. The code branches to chip select 1 so the code can continue executing from the non-remapped memory location.
5. The appropriate values are programmed into the memory controller to configure chip select 4, and the memory device is initialized.
6. The address mirroring is disabled by clearing the address mirror (M) field in the Control register (see page 278).
7. The ARM reset and interrupt vectors are copied from flash memory to SDRAM that can then be accessed at address `0x00000000`.
8. More boot, initialization, or application code is executed.

Static memory controller

Table 88 shows configurations for the static memory controller with different types of memory devices. See "Static Memory Configuration 0–3 registers" on page 303 for more information.

Device	Write protect	Page mode	Buffer
ROM	Enabled	Disabled	Disabled [a]
Page mode ROM	Enabled	Enabled	Enabled [a]
Extended wait ROM	Enabled	Disabled	Disabled [a]
SRAM	Disabled (or enabled) [b]	Disabled	Disabled [a]
Page mode SRAM	Disabled (or enabled) [b]	Enabled	Enabled [a]
Extended wait SRAM	Disabled (or enabled) [b]	Disabled	Disabled [a]
Flash	Disabled or (enabled) [b]	Disabled	Disabled [c]
Page mode flash	Disabled or (enabled) [b]	Enabled	Enabled [c]
Extended wait flash	Disabled or (enabled) [b]	Disabled	Disabled [a]
Memory mapped peripheral	Disabled (or enabled) [b]	Disabled	Disabled

a Enabling the buffers means that any access causes the buffer to be used. Depending on the application, this can provide performance improvements. Devices without async-page-mode support generally work better with the buffer disabled. Again, depending on the application, this can provide performance improvements.

b SRAM and Flash memory devices can be write-protected if required.

c Buffering must be disabled when performing Flash memory commands and during writes.

Table 88: Static memory controller configurations

Notes:

- Buffering enables the transaction order to be rearranged to improve memory performance. If the transaction order is important, the buffers must be disabled.
- Extended wait and page mode cannot be enabled at the same time.

Write protection

Each static memory chip select can be configured for write-protection. SRAM usually is unprotected and ROM devices must be write-protected (to avoid potential bus conflict when performing a write access to ROM), but the P field in the Static Memory Configuration register (see "Static Memory Configuration 0–3 registers" on page 303) can be set to write-protect SRAM as well as ROM devices. If a write access is made to

a write-protected memory bank, an error is indicated by the HRESP[1:0] signal. If a write access is made to a memory bank containing ROM devices and the chip select is not write-protected. An error is not returned and the write access proceeds as normal. Note that this might lead to a bus conflict.

Extended wait transfers

The static memory controller supports extremely long transfer times. In normal use, the memory transfers are timed using the Static Memory Read Delay register (StaticWaitRd, see "Static Memory Read Delay 0–3 registers" on page 309) and Static Memory Wait Delay register (StaticWaitWr, see "Static Memory Write Delay 0–3 registers" on page 311). These registers allow transfers with up to 32 wait states. If a very slow static memory device has to be accessed, however, you can enable the static configuration extended wait (EW) bit. When EW is enabled, the Static Extended Wait register ("Static Memory Extended Wait register" on page 297) is used to time both the read and write transfers. The Static Extended Wait register allows transfers to have up to 16368 wait states.

Notes:

- Using extremely long transfer times might mean that SDRAM devices are not refreshed correctly.
- Very slow transfers can degrade system performance, as the external memory interface is tied up for long periods of time. This has detrimental effects on time critical services, such as interrupt latency and low latency devices; for example, video controllers.

Memory mapped peripherals

Some systems use external peripherals that can be accessed using the static memory interface. Because of the way many of these peripherals function, the read and write transfers to them must not be buffered. The buffer must therefore be disabled.

Static memory initialization

Static memory must be initialized as required after poweron reset (reset_n) by programming the relevant registers in the memory controller as well as the configuration registers in the external static memory device.

Access sequencing and memory width

The data width of each external memory bank must be configured by programming the appropriate bank configuration register (Static Memory Configuration 0–3). When the external memory bus is narrower that the transfer initiated from the current main bus master, the internal bus transfer takes several external bus transfers to complete.

For example, if bank 0 is configured as 8-bit wide memory and a 32-bit read is initiated, the AHB bus stalls while the memory controller reads four consecutive bytes from the memory. During these accesses, the static memory controller block demultiplexes the four bytes into one 32-bit word on the AHB bus.

Wait state generation

Each bank of the memory controller must be configured for external transfer wait states in read and write accesses. Configure the banks by programming the appropriate bank control registers:

- "Static Memory Configuration 0–3 registers" on page 303 (StaticConfig[n])
- "Static Memory Write Enable Delay 0–3 registers" on page 307 (StaticWaitWen[n])
- "Static Memory Output Enable Delay 0–3 registers" on page 308 (StaticWaitOen[n])
- "Static Memory Read Delay 0–3 registers" on page 309 (StaticWaitRd[n])
- "Static Memory Write Delay 0–3 registers" on page 311 (StaticWaitWr[n])
- "Static Memory Page Mode Read Delay 0–3 registers" on page 310 (StaticWaitPage[n])
- "Static Memory Turn Round Delay 0–3 registers" on page 312 (StaticWaitTurn[n])
- "Static Memory Extended Wait register" on page 297 (StaticExtendedWait)

The number of cycles in which an AMBA transfer completes is controlled by two additional factors:

- Access width
- External memory width

Each bank of the memory controller has a programmable enable for the extended wait (EW). The WAITRD wait state field in the Static Memory Read Delay register can be programmed to select from 1–32 wait states for read memory accesses to SRAM and ROM, or the initial read access to page mode devices. The WAITWR wait state field in the Static Memory Write Delay register can be programmed to select from 1–32 wait states for access to SRAM. The Static Memory Page Mode Read Delay register can be programmed to select from 1–32 wait states for page mode accesses.

Static memory read control

There are three types of static memory read controls:

- Output enable programmable delay
- ROM, SRAM, and flash
- Asynchronous page mode read

Output enable programmable delay

The delay between the assertion of the chip select and the output enable is programmable from 0 to 15 cycles using the wait output enable bits (WAITOEN) in the Static Memory Output Enable Delay registers (see "Static Memory Output Enable Delay 0–3 registers" on page 308). The delay is used to reduce power consumption for memories that cannot provide valid output data immediately after the chip select has been asserted. The output enable is always deasserted at the same time as the chip select. at the end of the transfer.

ROM, SRAM, and Flash

The memory controller uses the same read timing control for ROM, SRAM, and flash devices. Each read starts with the assertion of the appropriate memory bank chip select signals (STCSOUT_n) and memory address (ADDROUT[27:0]). The read access time is determined by the number of wait states programmed for the WAITRD field in the Static Memory Read Delay register. The WAITTURN field in the Static Memory Turn round Delay register determines the number of bus turnaround wait states added between external read and write transfers.

Figure 45 shows an external memory read transfer with the minimum zero wait states (WAITRD=0). Cycles T0 through T4 are internal AHB bus cycles. These cycles are required to arbitrate for control of the AHB bus. Maximum performance is achieved when accessing the external device with load multiple (LDM) or store multiple (STM) CPU instructions. Table 89 provides the timing parameters. Table 90 describes the transactions in Figure 45.

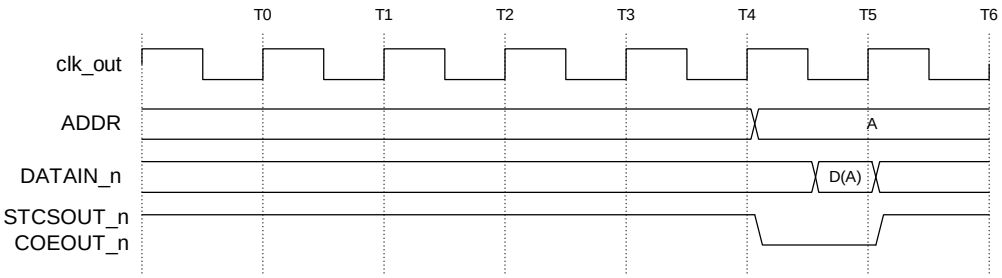


Figure 45: External memory 0 wait state read timing diagram

Timing parameter	Value
WAITRD	0
WAITOEN	0
WAITPAGE	N/A
WAITWR	N/A
WAITWEN	N/A
WAITTURN	N/A

Table 89: Static memory timing parameters

Cycle	Description
T0	AHB address provided to memory controller.
T0-T1	AHB transaction processing.
T1-T4	Arbitration of AHB memory ports.
T4-T5	Static memory address, chip select, and control signals submitted to static memory.
T5-T6	Read data returned from the static memory. Data is provided to AHB.

Table 90: External memory 0 wait state read

Figure 46 shows an external memory read transfer with two wait states (WAITRD=2). Seven AHB cycles are required for the transfer, five for the standard read access and an additional two because of the programmed wait states added (WAITRD). Table 91 provides the timing parameters. Table 92 describes the transactions in Figure 46.

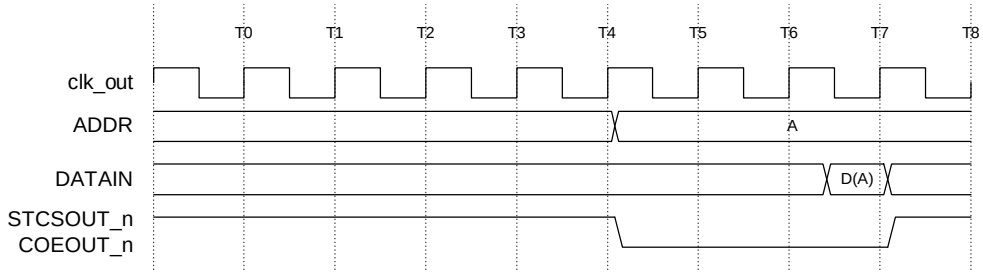


Figure 46: External memory 2 wait state read timing diagram

Timing parameter	Value
WAITRD	2
WAITOEN	0
WAITPAGE	N/A
WAITWR	N/A
WAITEN	N/A
WAITTURN	N/A

Table 91: Static memory timing parameters

Cycle	Description
T0	AHB address provided to memory controller.
T0-T1	AHB transaction processing.
T1-T4	Arbitration of AHB memory ports.
T4-T5	Static memory address, chip select, and control signals submitted to static memory.
T5-T6	Read wait state 1.
T6-T7	Read wait state 2.
T7-T8	Read data returned from the static memory. Data is provided to the AHB.

Table 92: External memory 2 wait state read

Figure 47 shows an external memory read transfer with two output enable delay states (`WAITOEN=2`). Seven AHB cycles are required for the transfer, five for the standard read and an additional two because of the output delay states added. Table 93 provides the timing parameters. Table 94 describes the transactions for Figure 47.

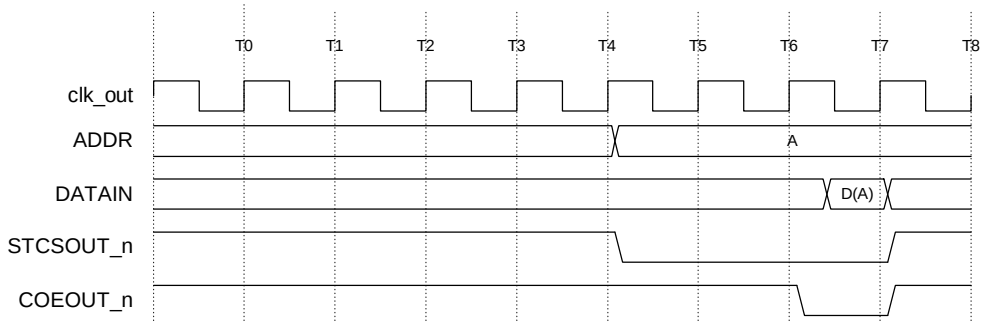


Figure 47: External memory 2 output enable delay state read timing diagram

Timing parameter	Value
WAITRD	2
WAITOEN	2
WAITPAGE	N/A
WAITWR	N/A
WAITWEN	N/A
WAITTURN	N/A

Table 93: Static memory timing parameters

Cycle	Description
T0	AHB address provided to memory controller.
T0-T1	AHB transaction processing.
T1-T4	Arbitration of AHB memory ports.
T4-T5	Static memory address, chip select, and control signals submitted to static memory. Static memory output enable inactive.
T5-T6	Static memory output enable inactive.
T6-T7	Static memory output enable active.
T7-T8	Read data returned from static memory. Data is provided to the AHB.

Table 94: External memory 2 output enable delay state

Figure 48 shows external memory read transfers with zero wait states (WAITRD=0). These transfers can be non-sequential transfers or sequential transfers of a specified burst length. Bursts of unspecified length are interpreted as INCR4 transfers. All transfers are treated as separate reads, so have the minimum of five AHB cycles added.

Table 95 provides the timing parameters. Table 96 describes the transactions for Figure 48.

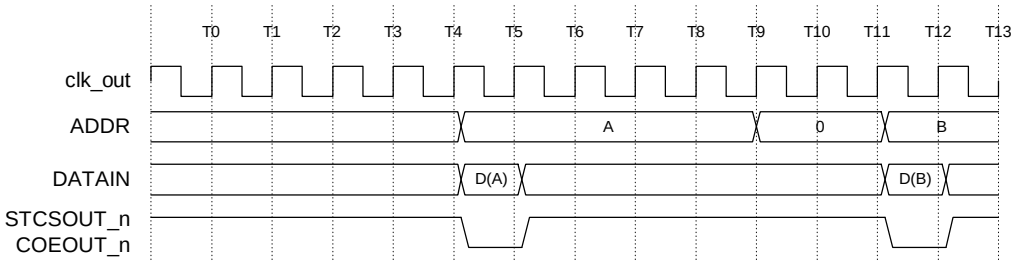


Figure 48: External memory 2 0 wait state read timing diagram

Timing parameter	Value
WAITRD	0
WAITOEN	0
WAITPAGE	N/A
WAITWR	N/A
WAITWEN	N/A
WAITTURN	N/A

Table 95: Static memory timing parameters

Cycle	Description
T0	AHB address provided to memory controller.
T0-T1	AHB transaction processing.
T1-T4	Arbitration of AHB memory ports.
T4-T5	Static memory address, chip select, and control signals submitted to static memory.
T5-T6	Read data returned to static memory. Data is provided to the AHB.

Table 96: External memory 2 0wait state reads

Cycle	Description
T6-T7	AHB address provided to memory controller. AHB transaction processing.
T7	AHB address provided to memory controller.
T7-T8	AHB transaction processing.
T8-T11	Arbitration of AHB memory ports.
T11-T12	Static memory address, chip select, and control signals submitted to static memory.
T12-T13	Read data returned from static memory. Data is provided to the AHB.

Table 96: External memory 2 0wait state reads

Figure 49 shows a burst of zero wait state reads with the length specified. Because the length of the burst is known, the chip select can be held asserted during the whole burst and generate the external transfers before the current AHB transfer has completed. The first read requires five arbitration cycles; the three subsequent sequential reads have zero AHB arbitration cycles added because the external transfers are automatically generated. Table 97 provides the timing parameters. Table 98 describes the transactions for Figure 49.

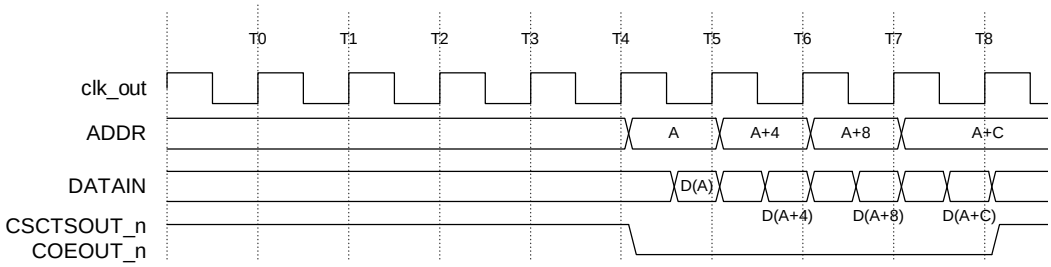


Figure 49: External memory 0 wait fixed length burst read timing diagram

Timing parameter	Value
WAITRD	0
WAITOEN	0

Table 97: SRAM timing parameters

Timing parameter	Value
WAITPAGE	N/A
WAITWR	N/A
WAITWEN	N/A
WAITTURN	N/A

Table 97: SRAM timing parameters

Cycle	Description
T0	AHB address provided to memory controller.
T0-T1	AHB transaction processing.
T1-T4	Arbitration of AHB memory ports.
T4-T5	Static memory read 0 address, chip select, and control signals submitted to static memory.
T5-T6	Static memory read 1 address, chip select, and control signals submitted to static memory. Read data 0 returned from static memory. Read data 0 is provided to the AHB.
T6-T7	Static memory read 2 address, chip select, and control signals submitted to static memory. read data 1 returned from the static memory. Read data 1 is provided to the AHB.
T7-T8	Static emory read 3 address, chip select, and control signals submitted to static memory. Read data 2 returned from the static memory. Read data 2 is provided to the AHB.
T8-T9	Read data 3 returned from the static memory. Read data 3 is provided to the AHB.

Table 98: External memory zero wait fixed length burst read

Figure 50 shows a burst of two wait state reads with the length specified. The WAITRD value is used for all transfers in the burst. Table 99 provides the timing parameters. Table 100 describes the transactions for Figure 50.

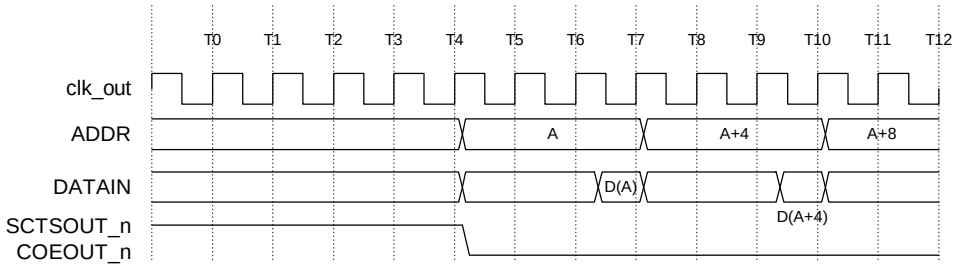


Figure 50: External memory 2 wait states fixed length burst read timing diagram

Timing parameter	Value
WAITRD	2
WAITOEN	0
WAITPAGE	N/A
WAITWR	N/A
WAITWEN	N/A
WAITTURN	N/A

Table 99: SRAM timing diagrams

Cycle	Description
T0	AHB address provided to memory controller.
T0-T1	AHB transaction processing.
T1-T4	Arbitration of memory ports.
T4-T5	Static memory address, chip select, and control signals submitted to static memory.
T5-T6	Read wait state 1.
T6-T7	Read wait state 2.

Table 100: External memory 2 wait states fixed length burst read

Cycle	Description
T7-T8	Read data 0 returned from the static memory. Read data 0 is provided to the AHB. Static memory transfer 1, address, chip select, and control signals submitted to static memory.
T8-T9	Read wait state 1.
T9-T10	Read wait state 2.
T10-T11	Read data 1 returned from the static memory. Read data 1 is provided to the AHB. Static memory transfer 2, address, chip select, and control signals submitted to static memory.
T11-T12	Read wait state 1.

Table 100: External memory 2 wait states fixed length burst read

Asynchronous page mode read

The memory controller supports asynchronous page mode read of up to four memory transfers by updating address bits A[1] and A[0]. This feature increases the bandwidth by using a reduced access time for the read accesses that are in page mode. The first read access takes static wait read and WAITRD cycles. Subsequent read accesses that are in page mode take static wait page and WAITPAGE cycles. The chip select and output enable lines are held during the burst, and only the lower two address bits change between subsequent accesses. At the end of the burst, the chip select and output enable lines are deasserted together.

Figure 51 shows an external memory page mode read transfer with two initial wait states and one sequential wait state. The first read requires five AHB arbitration cycles (plus three wait states); the following (up to 3) sequential transfers have only one AHB wait state. This gives increased performance over the equivalent nonpage mode ROM timing (see Figure 50, "External memory 2 wait states fixed length burst read timing diagram," on page 204). Table 101 provides the timing parameters. Table 102 describes the transactions for Figure 51.

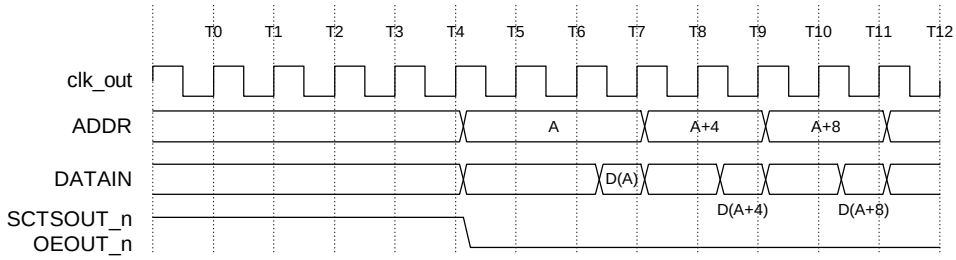


Figure 51: External memory page mode read transfer timing diagram

Timing parameter	Value
WAITRD	2
WAITOEN	0
WAITPAGE	1
WAITWR	N/A
WAITWEN	N/A
WAITTURN	N/A

Table 101: Static memory timing parameters

Cycle	Description
T0	AHB address provided to memory controller.
T0-T1	AHB transaction processing.
T1-T4	Arbitration of AHB memory ports.
T4-T5	Static memory transfer 0, address, chip select, and control signals submitted to static memory.
T5-T6	Read wait state 1.
T6-T7	Read wait state 2.
T7-T8	Read data 0 returned from static memory. Read data is provided to the AHB. Static memory transfer 1, address, chip select, and control signals submitted to static memory.

Table 102: External memory page mode read

Cycle	Description
T8-T9	Read page mode wait state 1.
T9-T10	Read data 1 returned from the static memory. Read data 1 is provided to the AHB. Static memory transfer 2, address, chip select, and control signals submitted to static memory.
T10-T11	Read page mode wait state 1.
T11-T12	Read data 2 returned from the static memory. Read data 2 is provided to the AHB. Static memory transfer 3, address, chip select, and control signals submitted to static memory.

Table 102: External memory page mode read

Figure 52 shows a 32-bit read from an 8-bit page mode ROM device, causing four burst reads to be performed. A total of eight AHB wait states are added during this transfer, five AHB arbitration cycles and then one for each of the subsequent reads. WAITRD and WAITPAGE are 0. Table 103 provides the timing parameters. Table 104 describes the transactions for Figure 52.

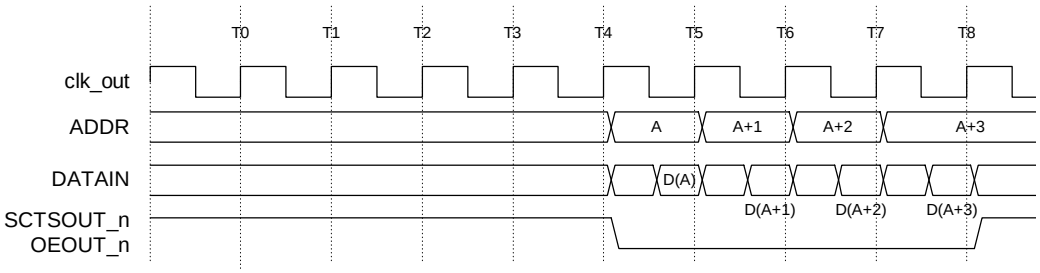


Figure 52: External memory 32-bit burst read from 8-bit memory timing diagram

Timing parameters	Value
WAITRD	0
WAITOEN	0
WAITPAGE	0

Table 103: Static memory timing parameters

Timing parameters	Value
WAITWR	N/A
WAITWEN	N/A
WAITTURN	N/A

Table 103: Static memory timing parameters

Cycle	Description
T0	AHB address provided to memory controller.
T0-T1	AHB transaction processing.
T1-T4	Arbitration of AHB memory ports.
T4-T5	Static memory transfer m0, address, chip select, and control signals submitted to static memory.
T5-T6	Static memory transfer 1, address, chip select, and control signals submitted to static memory. Read data byte 0 returned from static memory.
T6-T7	Static memory transfer 2, address, chip select, and control signals submitted to static memory. Read data byte 1 returned from the static memory.
T7-T8	Static memory transfer 3, address chip select, and control signals submitted to static memory. Read data byte 2 returned from the static memory.
T8-T9	Read data byte 3 returned from the static memory. Read data 32-bit word is provided to the AHB.

Table 104: External memory 32-bit burst read from 8-bit memory

Static memory write control

Write enable programming delay

The delay between the assertion of the chip select and the write enable is programmable from 0 to 15 cycles using the WAITWEN bits of the Static Memory Write Enable Delay (StaticWaitWen[3:0]) registers. The delay reduces the power consumption for memories. The write enable is asserted on the rising edge of HCLK after the assertion of the chip select for zero wait states. The write enable is always

deasserted a cycle before the chip select, at the end of the transfer. BLSOUT_n (byte lane signal) has the same timing as WEOUT_n (write enable signal) for writes to 8-bit devices that use the byte lane selects instead of the write enables.

SRAM

Write timing for SRAM starts with assertion of the appropriate memory bank chip selects (STCSOUT[n]_n) and address signals (ADDROUT[27:0]_n). The write access time is determined by the number of wait states programmed for the WAITWR field in the Static Memory Write Delay register (see "Static Memory Write Delay 0–3 registers" on page 311). The WAITTURN field in the bank control register (see "Static Memory Turn Round Delay 0–3 registers" on page 312) determines the number of bus turnaround wait states added between external read and write transfers.

Figure 53 shows a single external memory write transfer with minimum zero wait states (WAITWR=0). One wait state is added. Table 105 provides the timing parameters. Table 106 describes the transactions for Figure 53.

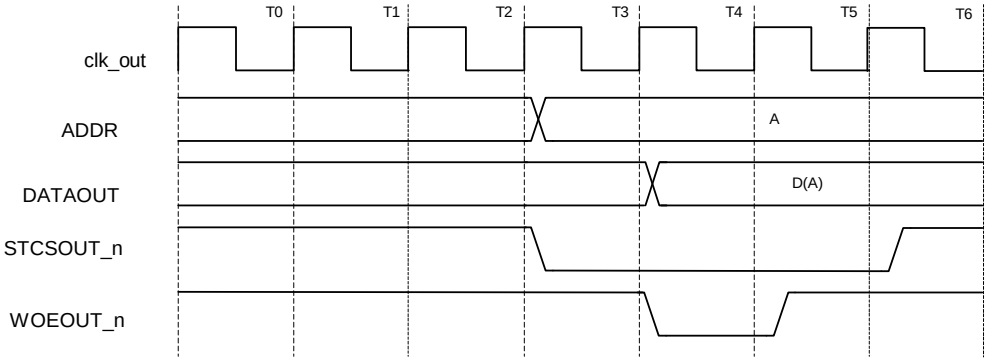


Figure 53: External memory 0 wait state write timing diagram

Timing parameters	Value
WAITRD	N/A
WAITOEN	N/A
WAITPAGE	N/A
WAITWR	0

Table 105: Static memory timing parameters

Timing parameters	Value
WAITWEN	0
WAITTURN	N/A

Table 105: Static memory timing parameters

Cycle	Description
T0	AHB address provided to memory controller.
T0-T1	AHB transaction processing.
T1-T4	Arbitration of AHB memory ports.
T4-T5	Static memory transfer 0, address, chip select, and control signals submitted to static memory. Write data is read from the AHB memory port. Write enable inactive.
T5-T6	Write enable taken active. Write data submitted to static memory. Static memory writes the data.
T6-T7	Static memory writes the data. Write enable taken inactive.
T7-T8	Static memory control signals taken inactive.

Table 106: External memory 0 wait state write

Figure 54 shows a single external memory write transfer with two wait states (WAITWR=2). One AHB wait state is added. Table 107 provides the timing parameters. Table 108 describes the transactions for Figure 54.

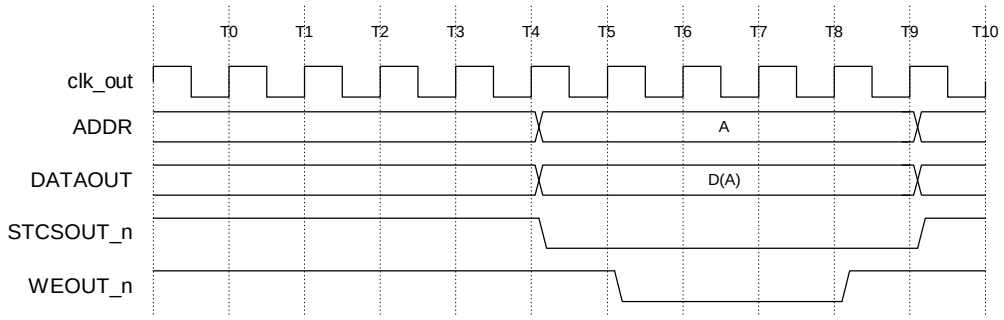


Figure 54: External memory 2 wait state write timing diagram

Timing parameter	Value
WAITRD	N/A
WAITOEN	N/A
WAITPAGE	N/A
WAITWR	2
WAITWEN	0
WAITTURN	N/A

Table 107: Static memory timing parameters

Cycle	Description
T0	AHB address provided to memory controller.
T0-T1	AHB transaction processing.
T1-T4	Arbitration of AHB memory ports.
T4-T5	Static memory transfer 0, address, chip select, and control signals submitted to static memory. Write data is read from the AHB memory port. Write enable inactive.
T5-T6	Write enable taken active. Write data submitted to static memory.

Table 108: External memory 2 wait state write

Cycle	Description
T6-T7	Wait state 1.
T7-T8	Wait state 2.
T8-T9	Static memory writes the data. Write enable taken inactive.
T9-T10	Static memory control signals taken inactive.

Table 108: External memory 2 wait state write

Figure 55 shows a single external memory write transfer with two write enable delay states (WAITWEN=2). One wait state is added. Table 109 provides the timing parameters.

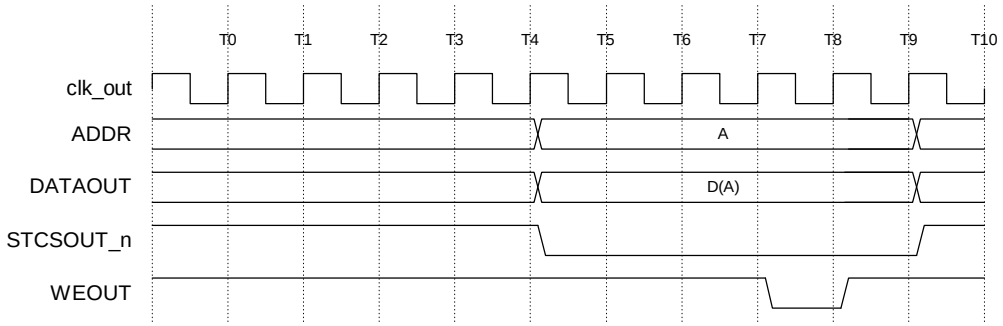


Figure 55: External memory 2 write enable delay write timing diagram

Timing parameters	Value
WAITRD	N/A
WAITOEN	N/A
WAITPAGE	N/A
WAITWR	2
WAITWEN	2
WAITTURN	N/A

Table 109: Static memory timing parameters

Cycle	Description
T0	AHB address provided to memory controller.
T0-T1	AHB transaction processing.
T1-T4	Arbitration of AHB memory ports.
T4-T5	Static memory transfer 0, address, chip select, and control signals submitted to static memory. Write data is read from the AHB memory port. Write enable active.
T5-T6	Write data submitted to static memory. Write enable wait state 1.
T6-T7	Write enable wait state 2.
T7-T8	Write enable taken active.
T8-T9	Static memory writes the data. Write enable taken inactive.
T9-T10	Static memory control signals taken inactive.

Table 110: External memory 2 write enable delay write

Figure 56 shows two external memory write transfers with zero wait states (WAITWR=0). Four AHB wait states are added to the second write, because this write can be started only when the first write has completed. This is the timing of any sequence of write transfers, nonsequential to nonsequential or nonsequential to sequential, with any value of HBURST. The maximum speed of write transfers is controlled by the external timing of the write enable relative to the chip select, so all external writes must take two cycles to complete: the cycle in which write enable is asserted and the cycle in which write enable is deasserted. Table 111 provides the timing parameters. Table 112 describes the transactions for Figure 56.

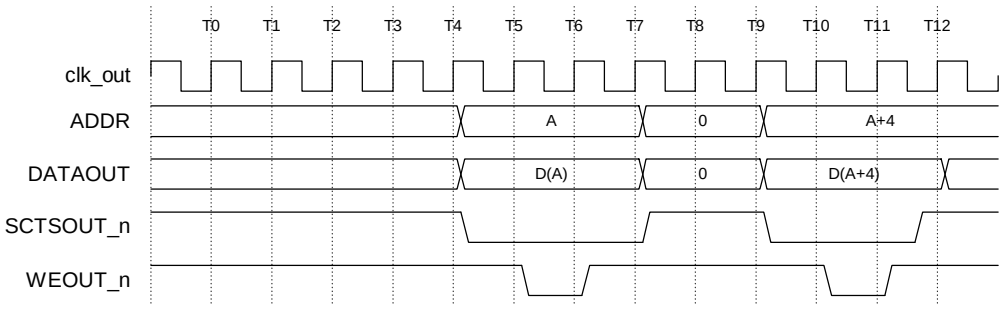


Figure 56: External memory 2 0 wait writes timing diagram

Timing parameter	Value
WAITRD	N/A
WAITOEN	N/A
WAITPAGE	N/A
WAITWR	0
WAITWEN	0
WAITTURN	0

Table 111: Static memory timing parameters

Cycle	Description
T0	AHB address provided to memory controller.
T0-T1	AHB transaction processing.
T1-T4	Arbitration of AHB memory ports.
T4-T5	Static memory transfer 0, address, chip select, and control signals submitted to static memory. Write data 0 is read from the AHB memory port. Write enable inactive.
T5-T6	Write enable taken active. Write data submitted to static memory.

Table 112: External memory 2 0 wait writes

Cycle	Description
T6-T7	Static memory writes data 0. Write enable taken inactive. Write data 1 is read from AHB memory port.
T7-T8	Static memory control signals taken inactive.
T8-T9	Memory controller processing.
T9-T10	Static memory transfer 1, address, chip select, and control signals submitted to static memory. Write enable inactive. Write data submitted to static memory.
T10-T11	Write enable taken active.
T11-T12	Static memory writes data 1. Write enable taken inactive.

Table 112: External memory 2 0 wait writes

Flash memory

Write timing for flash memory is the same as for SRAM devices.

Bus turnaround

The memory controller can be configured for each memory bank to use external bus turnaround cycles between read and write memory accesses. The WAITTURN field can be programmed for 1 to 16 turnaround wait states, to avoid bus contention on the external memory databus. Bus turnaround cycles are generated between external bus transfers as follows:

- Read to read (different memory banks
- Read to write (same memory bank)
- Read to write (different memory banks)

Figure 57 shows a zero wait read followed by a zero wait write with default turnaround between the transfers of two cycles because of the timing of the AHB transfers. Table 113 provides the timing parameters. Table 114 describes the transactions for Figure 57.

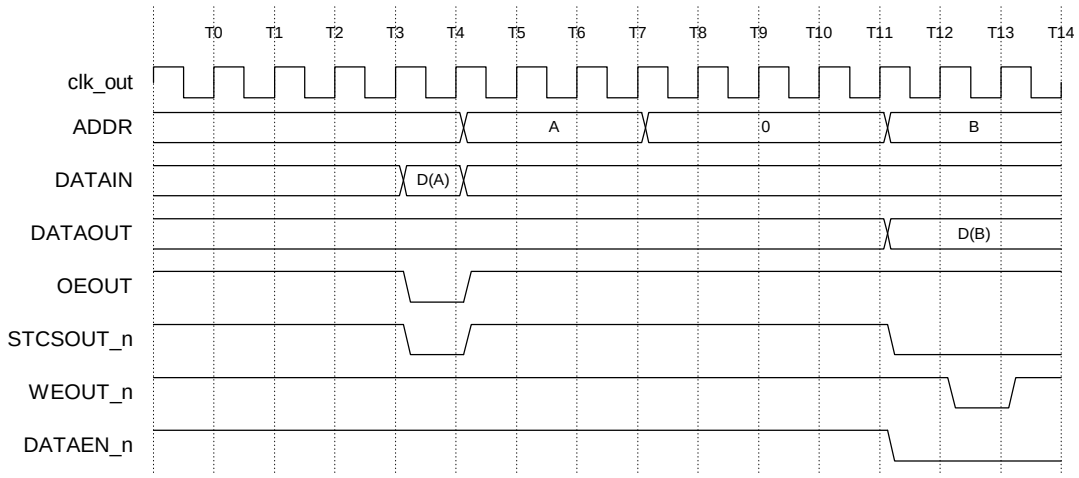


Figure 57: Read followed by write (both 0 wait) with no turnaround

Timing parameter	Value
WAITRD	0
WAITOEN	0
WAITPAGE	N/A
WAITWR	0
WAITWEN	0
WAITTURN	0

Table 113: Static memory timing parameters

Cycle	Description
T0	AHB address provided to the memory controller.
T0-T1	AHB transaction processing.
T1-T4	Arbitration of AHB memory ports.
T4-T5	AHB write address provided to memory controller.

Table 114: Read followed by write (both 0 wait) with no turnaround

Cycle	Description
T5-T6	Memory controller processing.
T6-T7	Memory controller processing.
T7-T8	Static memory transfer address, chip select, and control signals submitted to static memory. Write data is read from AHB memory port. Write enable inactive.
T8-T9	Write enable taken active. Write data submitted to static memory.
T9-T10	Static memory control signals taken inactive.
T10-T11	Memory controller processing.
T11-T12	Static memory transfer 1, address, chip select, and control signals submitted to static memory. Write enable inactive. Write data submitted to static memory.
T12-T13	Write enable taken active.
T13-T14	Static memory writes data 1. Write enable taken inactive.

Table 114: Read followed by write (both 0 wait) with no turnaround

Figure 58 shows a zero wait write followed by a zero wait read with default turnaround between the transfers of one cycle. Three wait states are added to the write transfer; five wait states are added to the read transfer. The five AHB arbitration cycles for the read transfer include two wait states to allow the previous write access to complete and the three standard wait states for the read transfer.

Table 115 provides the timing parameters. Table 116 describes the transactions for Figure 58.

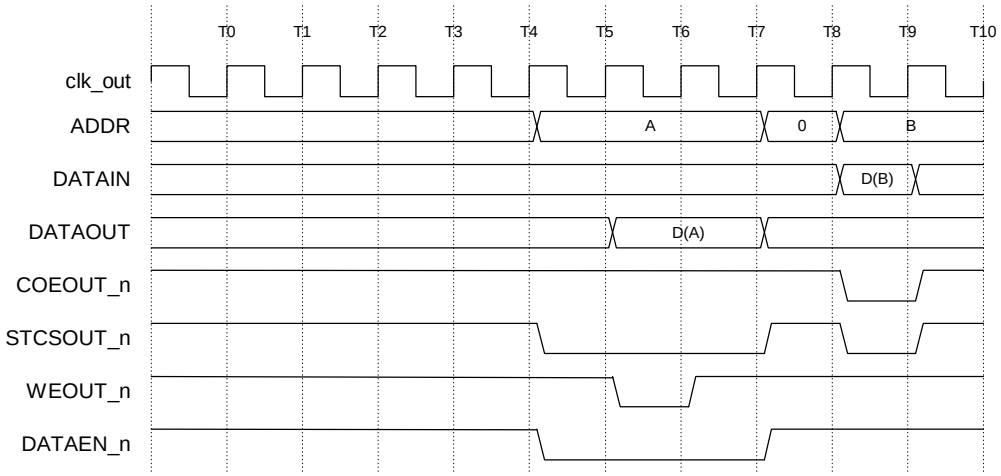


Figure 58: Write followed by a read (both 0 wait) with no turnaround

Timing parameters	Value
WAITRD	0
WAITOEN	0
WAITPAGE	N/A
WAITWR	0
WAITWEN	0
WAITTURN	0

Table 115: Static memory timing parameters

Cycle	Description
T0	AHB address provided to memory controller.
T0-T1	AHB transaction processing.
T1-T4	Arbitration of memory ports.

Table 116: Write followed by read (both 0 wait) with no turnaround

Cycle	Description
T4-T5	Static memory address, chip select, and control signals submitted to static memory. Write data is read from AHB memory port. Write enable inactive. AHB read address provided to memory controller.
T5-T6	Write enable taken active. Write data submitted to static memory.
T6-T7	Static memory writes the data. Write enable taken inactive.
T7-T8	Static memory control signals taken inactive.
T8-T9	Static memory address, chip select, and control signals submitted to static memory.
T9-T10	Read data returned from the static memory. Data is provided to the AHB.

Table 116: Write followed by read (both 0 wait) with no turnaround

Figure 59 shows a zero wait read followed by a zero wait write with two turnaround cycles added. The standard minimum of three AHB arbitration cycles are added to the read transfer and two wait states are added to the write transfer (as for any read-write transfer sequence).

Table 117 provides the timing parameters. Table 118 describes the transactions for Figure 59.

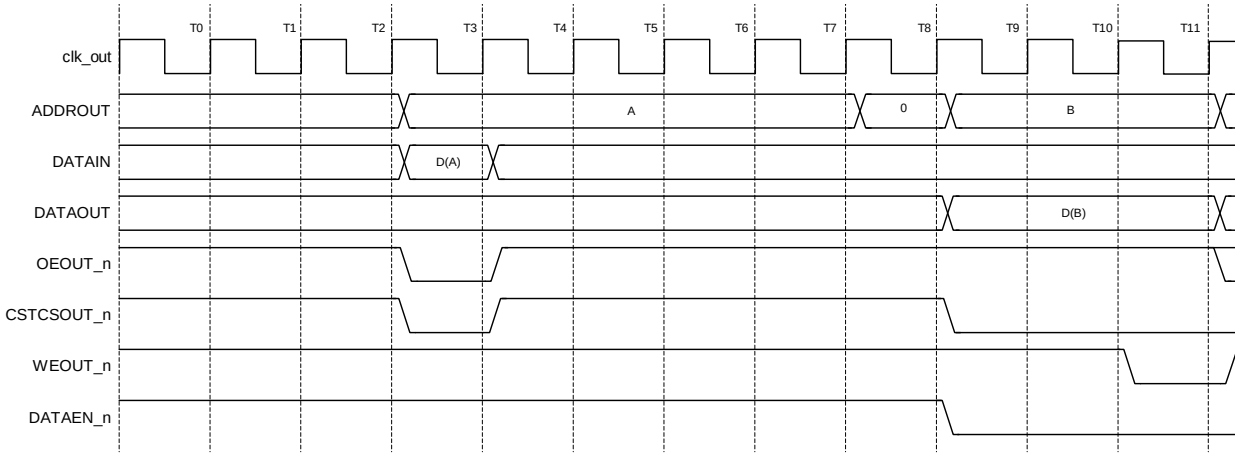


Figure 59: Read followed by a write (all 0 wait state) with two turnaround cycles

Timing parameters	Value
WAITRD	0
WAITOEN	0
WAITPAGE	N/A
WAITWR	0
WAITWEN	0
WAITTURN	2

Table 117: Static memory timing parameters

Cycle	Description
T0	AHB address provided to memory controller.
T0-T1	AHB transaction processing.
T1-T4	Arbitration of AHB memory ports.

Table 118: Read followed by a write (all 0 wait state) with two turnaround cycles

Cycle	Description
T4-T5	Static memory address, chip select, and control signals submitted to static memory.
T5-T6	Read data returned from static memory. Data is provided to the AHB. AHB write address provided to memory controller.
T6-T7	Turn around cycle 1.
T7-T8	Turn around cycle 2.
T8-T9	Static memory transfer address, chip select, and control signals submitted to static memory. Write enable inactive.
T9-T10	Memory controller processing.
T10-T11	Write enable taken active. Write data submitted to static memory.
T11-T12	Static memory writes the data. Write enable taken inactive.

Table 118: Read followed by a write (all 0 wait state) with two turnaround cycles

Byte lane control

The memory controller generates the byte lane control signals BLSOUT[3:0]_n according to these attributes:

- Little or big endian operation
- AMBA transfer width, indicated by HSIZE[2:0]
- External memory bank databus width, defined within each control register
- The decoded HADDR[1:0] value for write accesses only

Word transfers are the largest size transfers supported by the memory controller. Any access tried with a size greater that a word causes an error response. Each memory chip select can be 8, 16, or 32 bits wide. The memory type used determines how the WEOUT_n and BLSOUT_n signals are connected to provide byte, halfword, and word access.

For read accesses, you must control the BLSOUT_n signals by driving them all high or all low. Do this by programming the byte lane state (PB) bit in the Static

Configuration [3:0] register. "Memory banks constructed from 8-bit or non-byte-partitioned memory devices" on page 222 and "Memory banks constructed from 8-bit or non-byte-partitioned memory devices" on page 222 explain why different connections, with respect to WEOUT_n and BLSOUT[3:0]_n, for different memory configurations.

Address connectivity

The static memory address output signal ADDROUT[27:0] must be right-justified.

Memory banks constructed from 8-bit or non-byte-partitioned memory devices

For memory banks constructed from 8-bit or non-byte-partitioned memory devices, it is important that the byte lane state (PB) bit is cleared to 0 within the respective memory bank control register. This forces all BLSOUT[3:0]_n lines high during a read access, as the byte lane selects are connected to the device write enables.

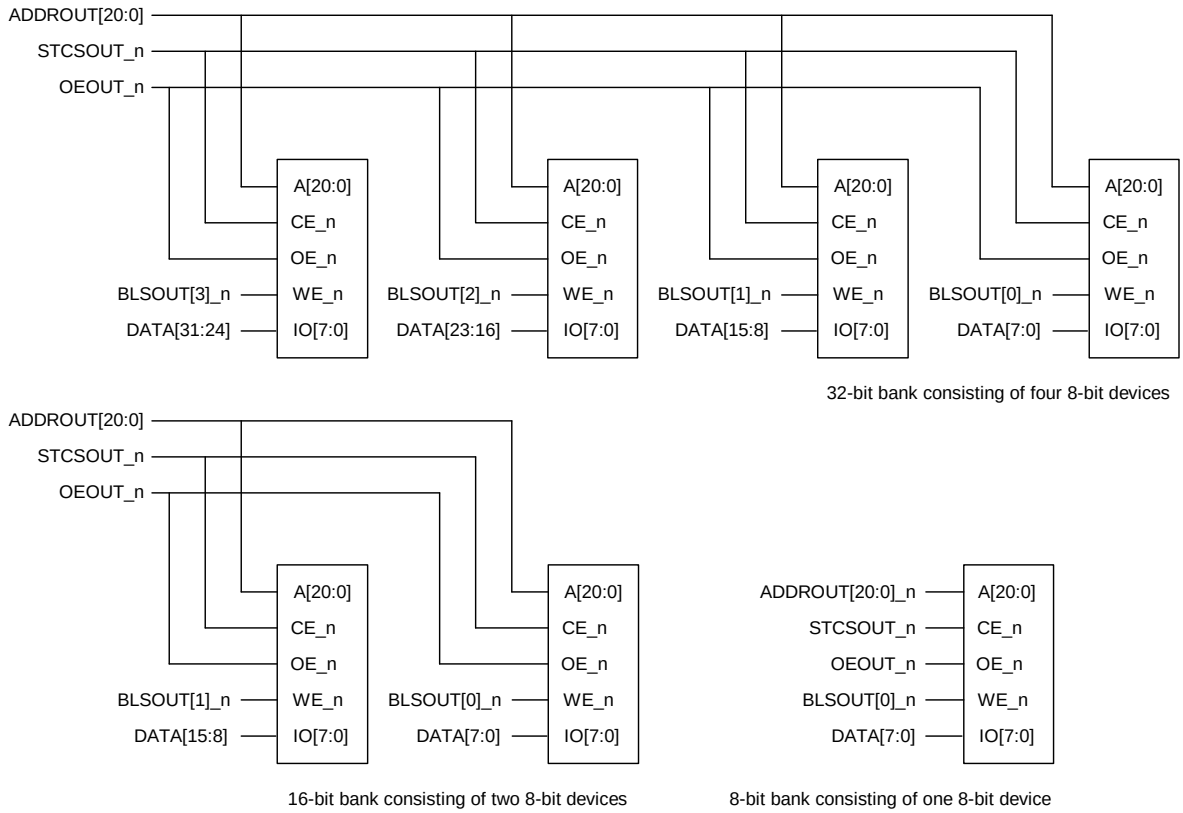


Figure 60: Memory banks constructed from 8-bit memory

Figure 60 shows 8-bit memory configuring memory banks that are 8-, 16-, and 32-bits wide. In each of these configurations, the `BLSOUT[3:0]_n` signals are connected to write enable (`WE_n`) inputs of each 8-bit memory. The `WEOUT` signal from the memory controller is not used.

- For write transfers, the appropriate `BLSOUT[3:0]_n` byte lane signals are asserted low, and direct the data to the addressed bytes.
- For read transfers, all `BLSOUT[3:0]_n` signals are deasserted high, enabling the external bus to be defined for at least the width of the accessed memory.

Memory banks constructed from 16-or 32-bit memory devices

For memory banks constructed from 16- or 32-bit memory devices, it is important that the byte lane select (PB) bit is set to 1 within the respective memory bank control register. This asserts all BLSOUT[3:0]_n lines low during a read access as, during a read, all device bytes must be selected to avoid undriven byte lanes on the read data value. With 16- and 32-bit wide memory devices, byte select signals exist and must be appropriately controlled; see Figure 61, "Memory banks constructed from 16-bit memory," on page 224 and Figure 62, "Memory banks constructed from 32-bit memory," on page 225.

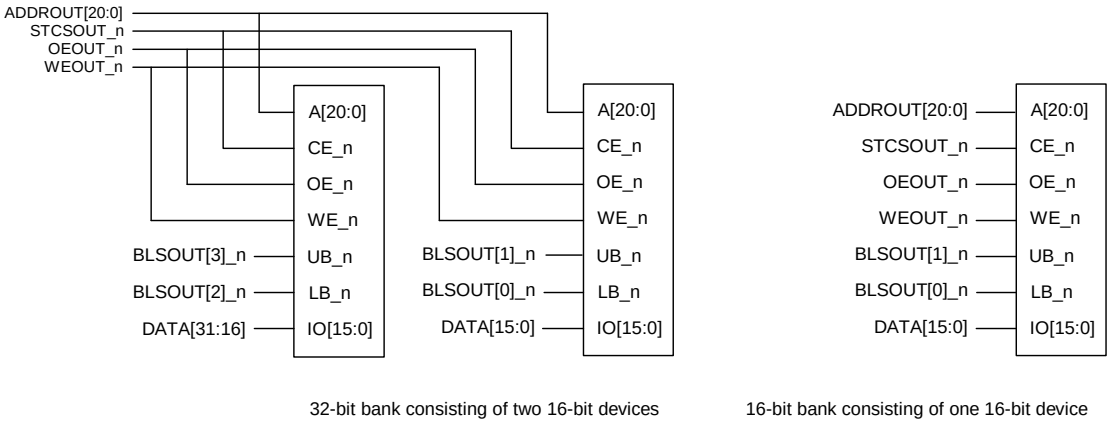


Figure 61: Memory banks constructed from 16-bit memory

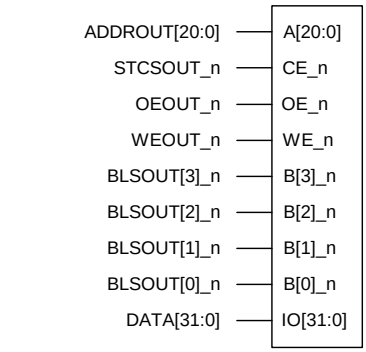


Figure 62: Memory banks constructed from 32-bit memory

Figure 63 shows connections for a typical memory system with different data width memory devices.

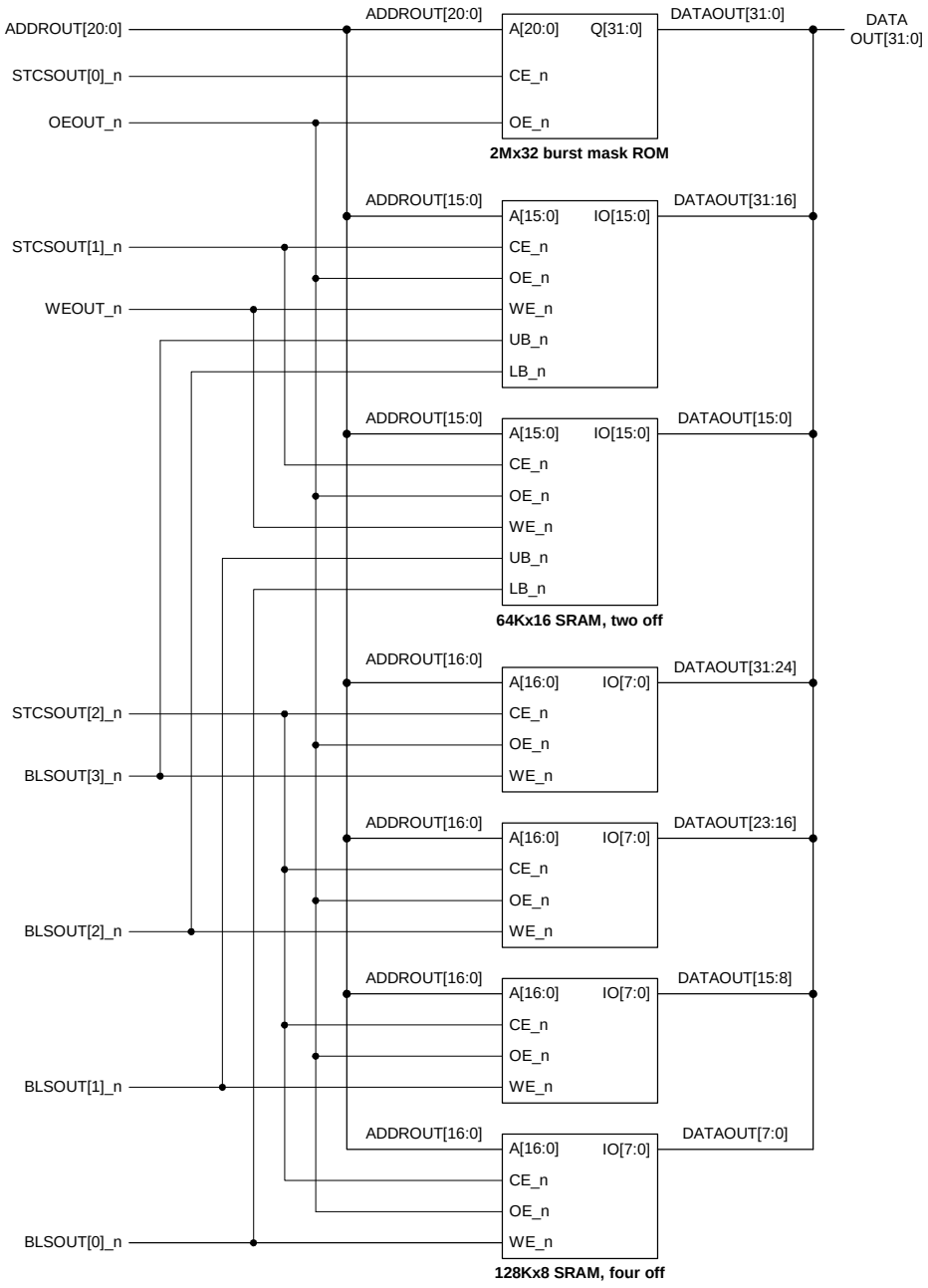


Figure 63: Typical memory connection diagram (1)

Byte lane control and databus steering

For little and big endian configurations, address right-justified

The tables in this section (Table 119 through Table 130) show the relationship of signals HSIZE[2:0], HADDR[1:0], ADDROUT[1:0], and BLSOUT[3:0] and mapping of data between the AHB system databus and the external memory databus. This mapping applies to both the static and dynamic memory controllers.

Internal transfer width	Access: Read, little endian, 8-bit external bus				External data mapping on to system databus			
					HRDATA to DATA			
	HSIZE [2:0]	HADDR [1:0]	ADDROUT [1:0]	BLSOUT [0]	[31:24]	23:16]	[15:8]	[7:0]
Word (4 transfers)	010	--	11	0	[7:0]	-	-	-
			10	0	-	[7:0]	-	-
			01	0	-	-	[7:0]	-
			00	0	-	-	-	[7:0]
Halfword (2 transfers)	001	1-	11	0	[7:0]	-	-	-
			10	0	-	[7:0]	-	-
Halfword (2 transfers)	001	0-	01	0	-	-	[7:0]	-
			00	0	-	-	-	[7:0]
Byte	000	11	11	0	[7:0]	-	-	-
Byte	000	10	10	0	-	[7:0]	-	-
Byte	000	01	01	0	-	-	[7:0]	-
Byte	000	00	00	0	-	-	-	[7:0]

Table 119: Little endian read, 8-bit external bus

Internal transfer width	Access: Read, little endian, 16-bit external bus				External data mapping on to system databus			
					HRDATA to DATA			
	HSIZE [2:0]	HADDR [1:0]	ADDROUT [0]	BLSOUT [1:0]	[31:24]	23:16]	[15:8]	[7:0]
Word (2 transfers	010	--	1	00	[15:8]	[7:0]	-	-
			0	00	-	-	[15:8]	[7:0]
Halfword	001	1-	1	00	[15:8]	[7:0]	-	-
Halfword	001	0-	0	00	-	-	[15:8]	[7:0]
Byte	000	11	1	01	[15:8]	-	-	-
Byte	000	10	1	10	-	[7:0]	-	-
Byte	000	01	0	01	-	-	[15:8]	-
Byte	000	00	0	10	-	-	-	[7:0]

Table 120: Little endian read, 16-bit external bus

Internal transfer width	Access: Read, little endian, 32-bit external bus			External data mapping on to system databus			
				HRDATA to DATA			
	HSIZE [2:0]	HADDR [1:0]	BLSOUT [3:0]	[31:24]	[23:16]	[15:8]	[7:0]
Word	010	--	0000	[31:24]	[23:16]	[15:8]	[7:0]
Halfword	001	1-	0011	[31:24]	[23:16]	-	-
Halfword (2 transfers)	001	0-	1100	-	-	[15:8]	[7:0]
Byte	000	11	0111	[31:24]	-	-	-
Byte	000	10	1011	-	[23:16]	-	-

Table 121: Little endian read, 32-bit external bus

Internal transfer width	Access: Read, little endian, 32-bit external bus			External data mapping on to system databus			
				HRDATA to DATA			
	HSIZE [2:0]	HADDR [1:0]	BLSOUT [3:0]	[31:24]	[23:16]	[15:8]	[7:0]
Byte	000	01	1101	-	-	[15:8]	-
Byte	000	00	1110	-	-	-	[7:0]

Table 121: Little endian read, 32-bit external bus

Internal transfer width	Access: Write, little endian, 8-bit external bus				System data mapping on to external databus			
					DATA to HRDATA			
	HSIZE [2:0]	HADDR [1:0]	ADDROUT [1:0]	BLSOUT [0]	[31:24]	[23:16]	[15:8]	[7:0]
Word (4 transfers	010	--	11	0	-	-	-	[31:24]
			10	0	-	-	-	[23:16]
			01	0	-	-	-	[15:8]
			00	0	-	-	-	[7:0]
Halfword (2 transfers)	001	1-	11	0	-	-	-	[31:24]
			10	0	-	-	-	[23:16]
Halfword (2 transfers)	001	0-	01	0	-	-	-	[15:8]
			00	0	-	-	-	[7:0]
Byte	000	11	11	0	-	-	-	[31:24]
Byte	000	10	10	0	-	-	-	[23:16]
Byte	000	01	01	0	-	-	-	[15:8]
Byte	000	00	00	0	-	-	-	[7:0]

Table 122: Little endian write, 8-bit external bus

Internal transfer width	Access: Write, little endian, 16-bit external bus				System data mapping on to external databus			
					DATA to HRDATA			
	HSIZE [2:0]	HADDR [1:0]	ADDROUT [0]	BLSOUT [1:0]	[31:24]	[23:16]	[15:8]	[7:0]
Word (2 transfers	010	--	1	00	--	-	[31:24]	[23:16]
			0	00	-	-	[15:8]	[7:0]
Halfword	001	1-	1	00	-	-	[31:24]	[23:16]
Halfword	001	0-	0	00	-	-	[15:8]	[7:0]
Byte	000	11	1	01	-	-	[31:24]	-
Byte	000	10	1	10	-	-	-	[23:16]
Byte	000	01	0	01	-	-	[15:8]	-
Byte	000	00	0	10	-	-	-	[7:0]

Table 123: Little endian write, 16-bit external bus

Internal transfer width	Access: Write, little endian, 32-bit external bus			System data mapping on to external databus			
				DATA to HRDATA			
	HSIZE [2:0]	HADDR [1:0]	BLSOUT [3:0]	[31:24]	[23:16]	[15:8]	[7:0]
Word	010	--	0000	[31:24]	[23:16]	[15:8]	[7:0]
Halfword	001	1-	0011	[31:24]	[23:16]	-	-
Halfword	001	0-	1100	-	-	[15:8]	[7:0]
Byte	000	11	0111	[31:24]	-	-	-
Byte	000	10	1011	-	[23:16]	-	-
Byte	000	01	1101	-	-	[15:8]	-

Table 124: Little endian write, 32-bit external bus

Internal transfer width	Access: Write, little endian, 32-bit external bus			System data mapping on to external databus			
				DATA to HRDATA			
	HSIZE [2:0]	HADDR [1:0]	BLSOUT [3:0]	[31:24]	[23:16]	[15:8]	[7:0]
Byte	000	00	1110	-	-	-	[7:0]

Table 124: Little endian write, 32-bit external bus

Internal transfer width	Access: Read, big endian, 8-bit external bus				External data mapping on to system databus			
					HRDATA to DATA			
	HSIZE [2:0]	HADDR [1:0]	ADDROUT [1:0]	BLSOUT [0]	[31:24]	23:16]	[15:8]	[7:0]
Word (4 transfers	010	--	11	0	-	-	-	[7:0]
			10	0	-	-	[7:0]	-
			01	0	-	[7:0]	-	-
			00	0	[7:0]	-		-
Halfword (2 transfers)	001	1-	11	0	-	-	-	[7:0]
			10	0	-	-	[7:0]	-
Halfword (2 transfers)	001	0-	01	0	-	[7:0]	-	-
			00	0	[7:0]	-	-	-
Byte	000	11	11	0	-	-	-	[7:0]
Byte	000	10	10	0	-	-	[7:0]	-
Byte	000	01	01	0	-	[7:0]	-	-
Byte	000	00	00	0	[7:0]	-	-	-

Table 125: Big endian read, 8-bit external bus

Internal transfer width	Access: Read, big endian, 16-bit external bus				External data mapping on to system databus			
					HRDATA to DATA			
	HSIZE [2:0]	HADDR [1:0]	ADDROUT [0]	BLSOUT [1:0]	[31:24]	23:16]	[15:8]	[7:0]
Word (2 transfers	010	--	1	00	-	-	[15:8]	[7:0]
			0	00	[15:8]	[7:0]	-	-
Halfword	001	1-	1	00	-	-	[15:8]	[7:0]
Halfword	001	0-	0	00	[15:8]	[7:0]	-	-
Byte	000	11	1	10	-	-	-	[7:0]
Byte	000	10	1	01	-	-	[15:8]	-
Byte	000	01	0	10	-	[7:0]	-	-
Byte	000	00	0	01	[15:8]	-	-	-

Table 126: Big endian read, 16-bit external bus

Internal transfer width	Access: Read, big endian, 32-bit external bus			External data mapping on to system databus			
				HRDATA to DATA			
	HSIZE [2:0]	HADDR [1:0]	BLSOUT [3:0]	[31:24]	[23:16]	[15:8]	[7:0]
Word	010	--	0000	[31:24]	[23:16]	[15:8]	[7:0]
Halfword	001	1-	1100	-	-	[15:8]	[7:0]
Halfword (2 transfers)	001	0-	0011	[31:24]	[23:16]	-	-
Byte	000	11	1110	-	-	-	[7:0]

Table 127: Big endian read, 32-bit external bus

Internal transfer width	Access: Read, big endian, 32-bit external bus			External data mapping on to system databus			
				HRDATA to DATA			
	HSIZE [2:0]	HADDR [1:0]	BLSOUT [3:0]	[31:24]	[23:16]	[15:8]	[7:0]
Byte	000	10	1101	-	-	[15:8]	-
Byte	000	01	1011	-	[23:16]	-	-
Byte	000	00	0111	[31:24]	-	-	-

Table 127: Big endian read, 32-bit external bus

Internal transfer width	Access: Write, big endian, 8-bit external bus				System data mapping on to external databus			
					DATA to HRDATA			
	HSIZE [2:0]	HADDR [1:0]	ADDROUT [1:0]	BLSOUT [0]	[31:24]	[23:16]	[15:8]	[7:0]
Word (4 transfers	010	--	11	0	-	-	-	[7:0]
			10	0	-	-	-	[15:8]
			01	0	-	-	-	[23:16]
			00	0	-	-	-	[31:24]
Halfword (2 transfers)	001	1-	11	0	-	-	-	[7:0]
			10	0	-	-	-	[15:8]
Halfword (2 transfers)	001	0-	01	0	-	-	-	[23:16]
			00	0	-	-	-	[31:24]
Byte	000	11	11	0	-	-	-	[7:0]
Byte	000	10	10	0	-	-	-	[15:8]
Byte	000	01	01	0	-	-	-	[23:16]
Byte	000	00	00	0	-	-	-	[31:24]

Table 128: Big endian write, 8-bit external bus

Internal transfer width	Access: Write, big endian, 16-bit external bus				System data mapping on to external databus			
					DATA to HRDATA			
	HSIZE [2:0]	HADDR [1:0]	ADDROUT [0]	BLSOUT [1:0]	[31:24]	[23:16]	[15:8]	[7:0]
Word (2 transfers	010	--	1	00	--	-	[15:8][31:24]	[7:0]
			0	00	-	-		[23:16]
Halfword	001	1-	1	00	-	-	[15:8]	[7:0]
Halfword	001	0-	0	00	-	-	[31:24]	[23:16]
Byte	000	11	1	10	-	-	-	[7:0]
Byte	000	10	1	01	-	-	[15:8]	-
Byte	000	01	0	10	-	-	-	[23:16]
Byte	000	00	0	01	-	-	[31:24]	-

Table 129: Big endian write, 16-bit external bus

Internal transfer width	Access: Write, big endian, 32-bit external bus			System data mapping on to external databus			
				DATA			
	HSIZE [2:0]	HADDR [1:0]	BLSOUT [3:0]	[31:24]	[23:16]	[15:8]	[7:0]
Word	010	--	0000	[31:24]	[23:16]	[15:8]	[7:0]
Halfword	001	1-	1100	-	-	[15:8]	[7:0]
Halfword	001	0-	0011	[31:24]	[23:16]	-	-
Byte	000	11	1110	-	-	-	[7:0]
Byte	000	10	1101	-	-	[15:8]	-
Byte	000	01	1011	-	[23:16]	-	-

Table 130: Big endian write, 32-bit external bus

Internal transfer width	Access: Write, big endian, 32-bit external bus			System data mapping on to external databus			
				DATA			
	HSIZE [2:0]	HADDR [1:0]	BLSOUT [3:0]	[31:24]	[23:16]	[15:8]	[7:0]
Byte	000	00	0111	[31:24]	-	-	-

Table 130: Big endian write, 32-bit external bus

Dynamic memory controller

Write protection

Each dynamic memory chip select can be configured for write-protection by setting the appropriate bit in the write protect (P) field on the Dynamic Memory Configuration register (see "Dynamic Memory Configuration 0–3 registers" on page 298). If a write access is performed to a write-protected memory bank, an ERROR response is generated on the `HRESP[1:0]` signal.

Access sequencing and memory width

The data width of each chip select must be configured by programming the appropriate Dynamic Memory Configuration register. When the chip select data bus width is narrower than the transfer initiated from the current AMBA bus master, the internal bus transfer takes several external bus transfers to complete. If chip select 4 is configured as 16-bit wide memory, for example, and a 32-bit read is initiated, the AHB bus stalls while the memory controller reads two consecutive words from memory. During these accesses, the memory controller block demultiplexes the two 16-bit words into one 32-bit word and places the result onto the AHB bus.

Word transfers are the widest transfers supported by the memory controller. Any access tried with a size larger than a word generates an error response.

Address mapping

This section provides tables that show how AHB address bus addresses map to the external dynamic memory address ADDROUT[14:0] for different memory configurations and bus widths. The address mapping is selected by programming the address mapping bits in the Dynamic Memory Configuration registers (see "Dynamic Memory Configuration 0–3 registers" on page 298).

The information provided includes:

- **Memory controller output address (ADDROUT).** Indicates the address lines output from the memory controller.
- **Memory device connections.** Indicate the device signals that must be connected to the memory controller AddrOut lines.
- **AHB addresses to row address.** Indicates the input HADDR address bits used from the AHB transfer for the row access.
- **AHB address to column address.** Indicates the input HADDR address bits used from the AHB transfer for the column access.

Notes:

- For all tables in this section:
  - ** indicates that the bit is controlled by the SDRAM controller. The SDRAM controller always transfers 32-bits of data at a time. For chip selects with a 16-bit wide databus, the SDRAM controller performs two transfers: a column transfer with the lowest bit set to 0 and a column transfer with the lowest bit set to 1.
  - BA, BA0, and BA1 indicate the bank address signals. AP indicates the auto precharge signal (usually, address bit 10).
- Separate tables are provided for two different address mapping schemes: row, bank, column (RBC) or bank, row, column (BRC), and for 32-bit and 16-bit wide buses:
  - **32-bit wide databus address mappings, SDRAM (RBC)** (see "32-bit wide databus address mappings, SDRAM (RBC)" on page 237). These address mappings are used for 32-bit data bus chip select with SDR-SDRAM memory devices. The row-bank-column address mapping scheme allows memory accesses to be performed efficiently to nearby memory regions.

- **32-bit wide databus address mappings (BRC)** (see "32-bit wide databus address mappings (BRC)" on page 248). These address mappings are used for 32-bit data bus chip select with SDR-SDRAM or low power SDR-SDRAM. The bank-row-column address mapping scheme allows the low-power SDR-SDRAM memory features to be used efficiently.
- **16-bit wide databus address mappings, SDRAM (RBC)** (see "16-bit wide databus address mappings, SDRAM (RBC)" on page 258). These address mappings are used for 16-bit data bus chip select with SDR-SDRAM memory devices. The row-bank-column address mapping scheme allows memory accesses to be performed efficiently to nearby memory regions.
- **16-bit wide databus address mappings (BRC)** (see "16-bit wide databus address mappings (BRC)" on page 266). These address mappings are used for 16-bit data bus chip select with SDR-SDRAM and low-power SDR-SDRAM. The bank-row-column address mapping scheme allows the low-power SDR-SDRAM memory features to be used efficiently.

32-bit wide databus address mappings, SDRAM (RBC)

Table 131 through Table 143 show 32-bit wide databus address mappings for several SDRAM (RBC) devices.

Table 131 shows the outputs from the memory controller and the corresponding inputs to the 16M SDRAM (1Mx16, pin 13 used as bank select).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	-	-	-
13	BA	10	10
12	-	-	-
11	-	-	-
10	10/AP	21	AP
9	9	20	-
8	8	19	-
7	7	18	9

Table 131: Address mapping for 16M SDRAM (1Mx16, RBC)

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
6	6	17	8
5	5	16	7
4	4	15	6
3	3	14	5
2	2	13	4
1	1	12	3
0	0	11	2

Table 131: Address mapping for 16M SDRAM (1Mx16, RBC)

Table 132 shows the outputs from the memory controller and the corresponding inputs to the 16M SDRAM (2Mx8, pin 14 used as bank select).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA	11	11
13	-	-	-
12	-	-	-
11	-	-	-
10	10/AP	22	AP
9	9	21	-
8	8	20	10
7	7	19	9
6	6	18	8
5	5	17	7
4	4	16	6
3	3	15	5
2	2	14	4

Table 132: Address mapping for 16M SDRAM (2Mx8, RBC)

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
1	1	13	3
0	0	12	2

Table 132: Address mapping for 16M SDRAM (2Mx8, RBC)

Table 133 shows the outputs from the memory controller and the corresponding inputs to the 64M SDRAM (2Mx32, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	11	11
13	BA0	10	10
12	-	-	-
11	-	-	-
10	10/AP	22	AP
9	9	21	-
8	8	20	-
7	7	19	9
6	6	18	8
5	5	17	7
4	4	16	6
3	3	15	5
2	2	14	4
1	1	13	3
0	0	12	2

Table 133: Address mapping for 64M SDRAM (2Mx32, RBC)

Table 134 shows the outputs from the memory controller and the corresponding inputs to the 64M SDRAM (4Mx16, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	11	11
13	BA0	10	10
12	-	-	-
11	11	23	-
10	10/AP	22	AP
9	9	21	-
8	8	20	-
7	7	199	9
6	6	18	8
5	5	17	7
4	4	16	6
3	3	15	5
2	2	14	4
1	1	13	3
0	0	12	2

Table 134: Address mapping for 64M SDRAM (4Mx16, RBC)

Table 135 shows the outputs from the memory controller and the corresponding inputs to the 64 M SDRAM (8Mx8, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	11	11
13	BA0	12	12
12	-	-	-
11	11	24	-
10	10/AP	23	AP
9	9	22	-
8	8	21	10
7	7	20	9
6	6	19	8
5	5	18	7
4	4	17	6
3	3	16	5
2	2	15	4
1	1	14	3
0	0	13	2

Table 135: Address mapping for 64M SDRAM (8Mx8, RBC)

Table 136 shows the outputs from the memory controller and the corresponding inputs to the 128M SDRAM (4Mx32, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	11	11
13	BA0	10	10
12	-	-	-

Table 136: Address mapping for 128M SDRAM (4Mx32, RBC)

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
11	11	23	-
10	10/AP	22	AP
9	9	21	-
8	8	20	-
7	7	19	9
6	6	18	8
5	5	17	7
4	4	16	6
3	3	15	5
2	2	14	4
1	1	13	3
0	0	12	2

Table 136: Address mapping for 128M SDRAM (4Mx32, RBC)

Table 137 shows the outputs from the memory controller and the corresponding inputs to the 64M SDRAM (8Mx16, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	11	11
13	BA0	12	12
12	-	-	-
11	11	24	-
10	10/AP	23	AP
9	9	22	-
8	8	21	10
7	7	20	9

Table 137: Address mapping for 128 SDRAM (8Mx16, RBC)

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
6	6	19	8
5	5	18	7
4	4	17	6
3	3	16	5
2	2	15	4
1	1	14	3
0	0	13	2

Table 137: Address mapping for 128 SDRAM (8Mx16, RBC)

Table 138 shows the outputs from the memory controller and the corresponding inputs to the 128M SDRAM (16Mx8, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	13	13
13	BA0	12	12
12	12	-	-
11	11	25	-
10	10/AP	24	AP
9	9	23	11
8	8	22	10
7	7	21	9
6	6	20	8
5	5	19	7
4	4	18	6
3	3	17	5
2	2	16	4

Table 138: Address mapping for 128 SDRAM (16Mx8, RBC)

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
1	1	15	3
0	0	14	2

Table 138: Address mapping for 128 SDRAM (16Mx8, RBC)

Table 139 shows the outputs from the memory controller and the corresponding inputs to the 256M SDRAM (8Mx32, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	11	11
13	BA0	10	10
12	12	24	-
11	11	23	-
10	10/AP	22	AP
9	9	21	-
8	8	20	-
7	7	19	9
6	6	18	8
5	5	17	7
4	4	16	6
3	3	15	5
2	2	14	4
1	1	13	3
0	0	12	2

Table 139: Address mapping for 256 SDRAM (8Mx32, RBC)

Table 140 shows the outputs from the memory controller and the corresponding inputs to the 256M SDRAM (16Mx16, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	11	11
13	BA0	12	12
12	12	25	-
11	11	24	-
10	10/AP	23	AP
9	9	22	-
8	8	21	10
7	7	20	9
6	6	19	8
5	5	18	7
4	4	17	6
3	3	16	5
2	2	15	4
1	1	14	3
0	0	13	2

Table 140: Address mapping for 256M SDRAM (16Mx16, RBC)

Table 141 shows the outputs from the memory controller and the corresponding inputs to the 256M SDRAM (32Mx8, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	13	13
13	BA0	12	12
12	12	26	-

Table 141: Address mapping for 256M SDRAM (32Mx8, RBC)

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
11	11	25	-
10	10/AP	24	AP
9	9	23	11
8	8	22	10
7	7	21	9
6	6	20	8
5	5	19	7
4	4	18	6
3	3	17	5
2	2	16	4
1	1	15	3
0	0	14	2

Table 141: Address mapping for 256M SDRAM (32Mx8, RBC)

Table 142 shows the outputs from the memory controller and the corresponding inputs to the 512M SDRAM (32Mx16, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	13	13
13	BA0	12	12
12	12	26	-
11	11	25	-
10	10/AP	24	AP
9	9	23	11
8	8	22	10
7	7	21	9

Table 142: Address mapping for 512M SDRAM (32Mx16, RBC)

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
6	6	20	8
5	5	19	7
4	4	18	6
3	3	17	5
2	2	16	4
1	1	15	3
0	0	14	2

Table 142: Address mapping for 512M SDRAM (32Mx16, RBC)

Table 143 shows the outputs from the memory controller and the corresponding inputs to the 512M SDRAM (64Mx8, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	13	13
13	BA0	14	14
12	12	27	-
11	11	26	12
10	10/AP	25	AP
9	9	24	11
8	8	23	10
7	7	22	9
6	6	21	8
5	5	20	7
4	4	19	6
3	3	18	5
2	2	17	4

Table 143: Address mapping for 512M SDRAM (64Mx8, RBC)

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
1	1	16	3
0	0	15	2

Table 143: Address mapping for 512M SDRAM (64Mx8, RBC)

32-bit wide databus address mappings (BRC)

Table 144 through Table 156 show 32-bit wide databus address mappings for several SDRAM (BRC) devices.

Table 144 shows the outputs from the memory controller and the corresponding inputs to the 16M SDRAM (1x16, pin 14 used as bank select).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA	21	21
13	-	-	-
12	-	-	-
11	-	-	-
10	10/AP	20	AP
9	9	19	-
8	8	18	-
7	7	17	9
6	6	16	8
5	5	15	7
4	4	14	6
3	3	13	5
2	2	12	4
1	1	11	3
0	0	10	2

Table 144: Address mapping for 16M SDRAM (1Mx16, BRC)

Table 145 shows the outputs from the memory controller and the corresponding inputs to the 16M SDRAM (2Mx8, pin 13 used as bank select).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	-	-	-
13	BA	22	22
12	-	-	-
11	-	-	-
10	10/AP	21	AP
9	9	20	-
8	8	19	10
7	7	18	9
6	6	17	8
5	5	16	7
4	4	15	6
3	3	14	5
2	2	13	4
1	1	12	3
0	0	11	2

Table 145: Address mapping for 16M SDRAM (2Mx8, BRC)

Table 146 shows the outputs from the memory controller and the corresponding inputs to the 64M SDRAM (2Mx32, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	21	21
13	BA0	22	22
12	-	-	-

Table 146: Address mapping for 64M SDRAM (2Mx32, BRC)

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
11	-	-	-
10	10/AP	20	AP
9	9	19	-
8	8	18	-
7	7	17	9
6	6	16	8
5	5	15	7
4	4	14	6
3	3	13	5
2	2	12	4
1	1	11	3
0	0	10	2

Table 146: Address mapping for 64M SDRAM (2Mx32, BRC)

Table 147 shows the outputs from the memory controller and the corresponding inputs to the 64M SDRAM (4Mx16, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	23	23
13	BA0	22	22
12	-	-	-
11	11	21	-
10	10/AP	20	AP
9	9	19	-
8	8	18	-
7	7	17	9

Table 147: Address mapping for 64M SDRAM (4Mx16, BRC)

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
6	6	16	8
5	5	15	7
4	4	14	6
3	3	13	5
2	2	12	4
1	1	11	3
0	0	10	2

Table 147: Address mapping for 64M SDRAM (4Mx16, BRC)

Table 148 shows the outputs from the memory controller and the corresponding inputs to the 64M SDRAM (8Mx8, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	23	23
13	BA0	24	24
12	-	-	-
11	11	22	-
10	10/AP	21	AP
9	9	20	-
8	8	19	10
7	7	18	9
6	6	17	8
5	5	16	7
4	4	15	6
3	3	14	5
2	2	13	4

Table 148: Address mapping for 64M SDRAM (8Mx8, BRC)

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
1	1	12	3
0	0	11	2

Table 148: Address mapping for 64M SDRAM (8Mx8, BRC)

Table 149 shows the outputs from the memory controller and the corresponding inputs to the 128M SDSRAM (4Mx32, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	23	23
13	BA0	22	22
12	-	-	-
11	11	21	-
10	10/AP	20	AP
9	9	19	-
8	8	18	-
7	7	17	9
6	6	16	8
5	5	15	7
4	4	14	6
3	3	13	5
2	2	12	4
1	1	11	3
0	0	10	2

Table 149: Address mapping for 128M SDRAM (4Mx32, BRC)

Table 150 shows the outputs from the memory controller and the corresponding inputs to the 128M SDRAM (8Mx16, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	23	23
13	BA0	24	24
12	-	-	-
11	11	22	-
10	10/AP	21	AP
9	9	20	-
8	8	19	10
7	7	18	9
6	6	17	8
5	5	16	7
4	4	15	6
3	3	14	5
2	2	13	4
1	1	12	3
0	0	11	2

Table 150: Address mapping for 128M SDRAM (8Mx16, BRC)

Table 151 shows the outputs from the memory controller and the corresponding inputs to the 128M SDRAM (16Mx8, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	25	25
13	BA0	24	24
12	12	-	-

Table 151: Address mapping for 128M SDRAM (16Mx8, BRC)

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
11	11	23	-
10	10/AP	22	AP
9	9	21	11
8	8	20	10
7	7	19	9
6	6	18	8
5	5	17	7
4	4	16	6
3	3	15	5
2	2	14	4
1	1	13	3
0	0	12	2

Table 151: Address mapping for 128M SDRAM (16Mx8, BRC)

Table 152 shows the outputs from the memory controller and the corresponding inputs to the 256M SDRAM (8Mx32, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	23	23
13	BA0	24	24
12	12	22	-
11	11	21	-
10	10/AP	20	AP
9	9	19	-
8	8	18	-
7	7	17	9

Table 152: Address mapping for 256M SDRAM (8Mx32, BRC)

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
6	6	16	8
5	5	15	7
4	4	14	6
3	3	13	5
2	2	12	4
1	1	11	3
0	0	10	2

Table 152: Address mapping for 256M SDRAM (8Mx32, BRC)

Table 153 shows the outputs from the memory controller and the corresponding inputs to the 256M SDRAM (16Mx16, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	25	25
13	BA0	24	24
12	12	23	-
11	11	22	-
10	10/AP	21	AP
9	9	20	-
8	8	19	10
7	7	18	9
6	6	17	8
5	5	16	7
4	4	15	6
3	3	14	5
2	2	13	4

Table 153: Address mapping for 256M SDRAM (16Mx16, BRC)

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
1	1	12	3
0	0	11	2

Table 153: Address mapping for 256M SDRAM (16Mx16, BRC)

Table 154 shows the outputs from the memory controller and the corresponding inputs to the 256M SDRAM (32Mx8, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	25	25
13	BA0	26	26
12	12	24	-
11	11	23	-
10	10/AP	22	AP
9	9	21	11
8	8	20	10
7	7	19	9
6	6	18	8
5	5	17	7
4	4	16	6
3	3	15	5
2	2	14	4
1	1	13	3
0	0	12	2

Table 154: Address mapping for 256M SDRAM (32Mx8, BRC)

Table 155 shows the outputs from the memory controller and the corresponding inputs to the 512M SDRAM (32Mx16, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	25	25
13	BA0	26	26
12	12	24	-
11	11	23	-
10	10/AP	22	AP
9	9	21	11
8	8	20	10
7	7	19	9
6	6	18	8
5	5	17	7
4	4	16	6
3	3	15	5
2	2	14	4
1	1	13	3
0	0	12	2

Table 155: Address mapping for 512M SDRAM (32Mx16, BRC)

Table 156 shows the outputs from the memory controller and the corresponding inputs to the 512M SDRAM (64Mx8, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	27	27
13	BA0	26	26
12	12	25	-

Table 156: Address mapping for 512M SDRAM (64x8, BRC)

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
11	11	24	12
10	10/AP	23	AP
9	9	22	11
8	8	21	10
7	7	20	9
6	6	19	8
5	5	18	7
4	4	17	6
3	3	16	5
2	2	15	4
1	1	14	3
0	0	13	2

Table 156: Address mapping for 512M SDRAM (64x8, BRC)

16-bit wide databus address mappings, SDRAM (RBC)

Table 157 through Table 166 show 16-bit wide databus address mappings for SDRAM (RBC) devices.

Table 157 shows the outputs from the memory controller and the corresponding inputs to the 16M SDRAM (1Mx16, pin 14 used as bank select).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA	9	9
13	-	-	-
12	-	-	-
11	-	-	-
10	10/AP	20	AP

Table 157: Address mapping for 16M SDRAM (1Mx16, RBC)

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
9	9	19	-
8	8	18	-
7	7	17	8
6	6	16	7
5	5	15	6
4	4	14	5
3	3	13	4
2	2	12	3
0	0	10	**

Table 157: Address mapping for 16M SDRAM (1Mx16, RBC)

Table 158 shows the outputs from the memory controller and the corresponding inputs to the 16M SDRAM (2Mx8, pin 13 used as bank select).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA	-	-
13	-	10	10
12	-	-	-
11	-	-	-
10	10/AP	11	AP
9	9	21	-
8	8	20	9
7	7	19	8
6	6	18	7
5	5	17	6

Table 158: Address mapping for 16M SDRAM (2Mx8, RBC)

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
4	4	16	5
3	3	15	4
2	2	14	3
1	1	13	2
0	0	12	**

Table 158: Address mapping for 16M SDRAM (2Mx8, RBC)

Table 159 shows the outputs from the memory controller and the corresponding inputs to the 64M SDRAM (4Mx16, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	9	9
13	BA0	10	10
12	-	-	-
11	11	22	-
10	10/AP	21	AP
9	9	20	-
8	8	19	-
7	7	18	8
6	6	17	7
5	5	16	6
4	4	15	5
3	3	14	4
2	2	13	3
1	1	12	2
0	0	11	**

Table 159: Address mapping for 64M SDRAM (4Mx16, RBC)

Table 160 shows the outputs from the memory controller and the corresponding inputs to the 64M SDRAM (8Mx8, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	11	11
13	BA0	10	10
12	-	-	-
11	11	23	-
10	10/AP	22	AP
9	9	21	-
8	8	20	9
7	7	19	8
6	6	18	7
5	5	17	6
4	4	16	5
3	3	15	4
2	2	14	3
1	1	13	2
0	0	12	**

Table 160: Address mapping for 64M SDRAM (8Mx8, RBC)

Table 161 shows the outputs from the memory controller and the corresponding inputs tot he 128M SDRAM (8Mx16, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	11	11
13	BA0	10	10
12	-	-	-

Table 161: Address mapping for 128M SDRAM (8Mx16, RBC)

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
11	11	23	-
10	10/AP	22	AP
9	9	21	-
8	8	20	9
7	7	19	8
6	6	18	7
5	5	17	6
4	4	16	5
3	3	15	4
2	2	14	3
1	1	13	2
0	0	12	**

Table 161: Address mapping for 128M SDRAM (8Mx16, RBC)

Table 162 shows the outputs from the memory controller and the corresponding inputs to the 128M SDRAM (16Mx8, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	11	11
13	BA0	12	12
12	-	-	-
11	11	24	-
10	10/AP	23	AP
9	9	22	10
8	8	21	9
7	7	20	8

Table 162: Address mapping for 128M SDRAM (16Mx8, RBC)

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
6	6	19	7
5	5	18	6
4	4	17	5
3	3	16	4
2	2	15	3
1	1	14	2
0	0	13	**

Table 162: Address mapping for 128M SDRAM (16Mx8, RBC)

Table 163 shows the outputs from the memory controller and the corresponding inputs to the 256M SDRAM (16Mx16, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	11	11
13	BA0	10	10
12	12	24	-
11	11	23	-
10	10/AP	22	AP
9	9	21	-
8	8	20	9
7	7	19	8
6	6	18	7
5	5	17	6
4	4	16	5
3	3	15	4
2	2	14	3

Table 163: Address mapping for 256M SDRAM (16Mx16, RBC)

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
1	1	13	2
0	0	12	**

Table 163: Address mapping for 256M SDRAM (16Mx16, RBC)

Table 164 shows the outputs from the memory controller and the corresponding inputs to the 256M SDRAM (32Mx8, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	11	11
13	BA0	12	12
12	12	25	-
11	11	24	-
10	10/AP	23	AP
9	9	22	10
8	8	21	9
7	7	20	8
6	6	19	7
5	5	18	6
4	4	17	5
3	3	16	4
2	2	15	3
1	1	14	2
0	0	13	**

Table 164: Address mapping for 256M SDRAM (32Mx8, RBC)

Table 165 shows the outputs from the memory controller and the corresponding inputs to the 512M SDRAM (32Mx16, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	11	11
13	BA0	12	12
12	12	25	-
11	11	24	-
10	10/AP	23	AP
9	9	22	10
8	8	21	9
7	7	20	8
6	6	19	7
5	5	18	6
4	4	17	5
3	3	16	4
2	2	15	3
1	1	14	2
0	0	13	**

Table 165: Address mapping for 512M SDRAM (32Mx16, RBC)

Table 166 shows the outputs from the memory controller and the corresponding inputs to the 512M SDRAM (64Mx8, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	13	13
13	BA0	12	12
12	12	26	-
11	11	25	11
10	10/AP	24	AP
9	9	23	10
8	8	22	9
7	7	21	8
6	6	20	7
5	5	19	6
4	4	18	5
3	3	17	4
2	2	16	3
1	1	15	2
0	0	14	**

Table 166: Address mapping for 512M SDRAM (64Mx8, RBC)

16-bit wide databus address mappings (BRC)

Table 167 through Table 176 show 16-bit wide databus address mappings for SDRAM (BRC) devices.

Table 167 shows the outputs from the memory controller and the corresponding inputs to the 16M SDRAM (1Mx16, pin 13 used as bank select).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	-	-	-
13	BA	20	20
12	-	-	-
11	-	-	-
10	10/AP	19	AP
9	9	18	-
8	8	17	-
7	7	16	8
6	6	15	7
5	5	14	6
4	4	13	5
3	3	12	4
2	2	11	3
1	1	10	2
0	0	9	**

Table 167: Address mapping for 16M SDRAM (1Mx16, BRC)

Table 168 shows the outputs from the memory controller and the corresponding inputs to the 16M SDRAM (2Mx8, pin 14 used as a bank select).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA	21	21
13	-	-	-
12	-	-	-
11	-	-	-
10	10/AP	20	AP

Table 168: Address mapping for 16M SDRAM (2Mx8, BRC)

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
9	9	19	-
8	8	18	9
7	7	17	8
6	6	16	7
5	5	15	6
4	4	14	5
3	3	13	4
2	2	12	3
1	1	11	2
0	0	10	**

Table 168: Address mapping for 16M SDRAM (2Mx8, BRC)

Table 169 shows the outputs from the memory controller and the corresponding inputs to the 64M SDRAM (4Mx16, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	21	21
13	BA0	22	22
12	-	-	-
11	11	20	-
10	10/AP	19	AP
9	9	18	-
8	8	17	-
7	7	16	8
6	6	15	7
5	5	14	6

Table 169: Address mapping for 64M SDRAM (4Mx16, BRC)

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
4	4	13	5
3	3	12	4
2	2	11	3
1	1	10	2
0	0	9	**

Table 169: Address mapping for 64M SDRAM (4Mx16, BRC)

Table 170 shows the outputs from the memory controller and the corresponding inputs to the 64M SDRAM (8Mx*, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	23	23
13	BA0	22	22
12	-	-	-
11	11	21	-
10	10/AP	20	AP
9	9	19	-
8	8	18	9
7	7	17	8
6	6	16	7
5	5	15	6
4	4	14	5
3	3	13	4
2	2	12	3
1	1	11	2
0	0	10	**

Table 170: Address mapping for 64M SDRAM (8Mx8, BRC)

Table 171 shows the outputs from the memory controller and the corresponding inputs to the 128M SDRAM (8Mx16, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	23	23
13	BA0	22	22
12	-	-	-
11	11	21	-
10	10/AP	20	AP
9	9	19	-
8	8	18	9
7	7	17	8
6	6	16	7
5	5	15	6
4	4	14	5
3	3	13	4
2	2	12	3
1	1	11	2
0	0	10	**

Table 171: Address mapping for 128M SDRAM (8Mx16, BRC)

Table 172 shows the outputs from the memory controller and the corresponding inputs to the 128 SDRAM (16Mx8, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	23	23
13	BA0	24	24
12	-	-	-

Table 172: Address mapping for 128M SDRAM (16Mx8, BRC)

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
11	11	22	-
10	10/AP	21	AP
9	9	20	10
8	8	19	9
7	7	18	8
6	6	17	7
5	5	16	6
4	4	15	5
3	3	14	4
2	2	13	3
1	1	12	2
0	0	11	**

Table 172: Address mapping for 128M SDRAM (16Mx8, BRC)

Table 173 shows the outputs for the memory controller and the corresponding inputs to the 256M SDRAM (16Mx16, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	23	23
13	BA0	24	24
12	12	22	-
11	11	21	-
10	10/AP	20	AP
9	9	19	-
8	8	18	9
7	7	17	8

Table 173: Address mapping for 256M SDRAM (16Mx16, BRC)

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
6	6	16	7
5	5	15	6
4	4	14	5
3	3	13	4
2	2	12	3
1	1	11	2
0	0	10	**

Table 173: Address mapping for 256M SDRAM (16Mx16, BRC)

Table 174 shows the outputs for the memory controller and the corresponding inputs to the 256M SDRAM (32Mx8, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	25	25
13	BA0	24	24
12	12	23	-
11	11	22	-
10	10/AP	21	AP
9	9	20	10
8	8	19	9
7	7	18	8
6	6	17	7
5	5	16	6
4	4	15	5
3	3	14	4
2	2	13	3

Table 174: Address mapping for 256M SDRAM (32Mx8, BRC)

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
1	1	12	2
0	0	11	**

Table 174: Address mapping for 256M SDRAM (32Mx8, BRC)

Table 175 shows the outputs from the memory controller and the corresponding inputs to the 512M SDRAM (32Mx16, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	25	25
13	BA0	24	24
12	12	23	-
11	11	22	-
10	10/AP	21	AP
9	9	20	10
8	8	19	9
7	7	18	8
6	6	17	7
5	5	16	6
4	4	15	5
3	3	14	4
2	2	13	3
1	1	12	2
0	0	11	**

Table 175: Address mapping for 512M SDRAM (32Mx16, BRC)

Table 176 shows the outputs from the memory controller and the corresponding inputs to the 512M SDRAM (64Mx8, pins 13 and 14 used as bank selects).

Output address (ADDROUT)	Memory device connections	AHB address to row address	AHB address to column address
14	BA1	26	26
13	BA0	25	25
12	12	24	-
11	11	23	11
10	10/AP	22	AP
9	9	21	10
8	8	20	9
7	7	19	8
6	6	18	7
5	5	17	6
4	4	16	5
3	3	15	4
2	2	14	3
1	1	13	2
0	0	12	**

Table 176: Address mapping for 512M SDRAM (64Mx8, BRC)

Registers

The external memory is accessed using the AHB memory interface ports. Addresses are not fixed, but are determined by the AHB decoder and can be different for any particular system implementation. Transfers to the external memory controller memories are selected by the HSELMPMC[3:0]CS[7:0] signals (where [3:0] indicates the AHB port number and [7:0] indicates the chip select to be accessed.)

Register map

Table 177 lists the registers in the Memory Controller register map. All configuration registers must be accessed as 32-bit words and as single accesses only. No bursting is allowed.

Address	Register	Description
A070 0000	Control register	Control register
A070 0004	Status register	Status register
A070 0008	Config register	Configuration register
A070 0020	DynamicControl	Dynamic Memory Control register
A070 0024	DynamicRefresh	Dynamic Memory Refresh Timer
A070 0028	DynamicReadConfig	Dynamic Memory Read Configuration register
A070 0030	DynamictRP	Dynamic Memory Precharge Command Period (t_{RP})
A070 0034	DynamictRAS	Dynamic Memory Active to Precharge Command Period (t_{RAS})
A070 0038	DynamictSREX	Dynamic Memory Self-Refresh Exit Time (t_{SREX})
A070 003C	DynamictAPR	Dynamic Memory Last Data Out to Active Time (t_{APR})
A070 0040	DynamictDAL	Dynamic Memory Data-in to Active Command Time (t_{DAL} or T_{APW})
A070 0044	DynamictWR	Dynamic Memory Write Recovery Time (t_{WR}, t_{DPL}, t_{RWL}, t_{RDL})

Table 177: Memory Controller register map

Address	Register	Description
A070 0048	DynamictRC	Dynamic Memory Active to Active Command Period (t_{RC})
A070 004C	DynamictRFC	Dynamic Memory Auto Refresh Period, and Auto Refresh to Active Command Period (t_{RFC})
A070 0050	DynamictXSR	Dynamic Memory Exit Self-Refresh to Active Command (t_{XSR})
A070 0054	DynamictRRD	Dynamic Memory Active Bank A to Active B Time (t_{RRD})
A070 0058	DynamictMRD	Dynamic Memory Load Mode register to Active Command Time (t_{MRD})
A070 0080	StaticExtendedWait	Static Memory Extended Wait
A070 0100	DynamicConfig0	Dynamic Memory Configuration Register 0
A070 0104	DynamicRasCas0	Dynamic Memory RAS and CAS Delay 0
A070 0120	DynamicConfig1	Dynamic Memory Configuration Register 1
A070 0124	DynamicRasCas1	Dynamic Memory RAS and CAS Delay 1
A070 0140	DynamicConfig2	Dynamic Memory Configuration Register 2
A070 0144	DynamicRasCas2	Dynamic Memory RAS and CAS Delay 2
A070 0160	DynamicConfig3	Dynamic Memory Configuration Register 3
A070 0164	DynamicRasCas3	Dynamic Memory RAS and CAS Delay 3
A070 0200	StaticConfig0	Static Memory Configuration Register 0
A070 0204	StaticWaitWen0	Static Memory Write Enable Delay 0
A070 0208	StaticWaitOen0	Static Memory Output Enable Delay 0
A070 020C	StaticWaitRd0	Static Memory Read Delay 0
A070 0210	StaticWaitPage0	Static Memory Page Mode Read Delay 0
A070 0214	StaticWaitWr0	Static Memory Write Delay 0
A070 0218	StaticWaitTurn0	Static Memory Turn Round Delay 0
A070 0220	StaticConfig1	Static Memory Configuration Register 1
A070 0224	StaticWaitWen1	Static Memory Write Enable Delay 1
A070 0228	StaticWaitOen1	Static Memory Output Enable Delay 1

Table 177: Memory Controller register map

Address	Register	Description
A070 022C	StaticWaitRd1	Static Memory Read Delay 1
A070 0230	StaticWaitPage1	Static Memory Page Mode Read Delay 1
A070 0234	StaticWaitWr1	Static Memory Write Delay 1
A070 0238	StaticWaitTurn1	Static Memory Turn Round Delay 1
A070 0240	StaticConfig2	Static Memory Configuration Register 2
A070 0244	StaticWaitWen2	Static Memory Write Enable Delay 2
A070 0248	StaticWaitOen2	Static Memory Output Enable Delay 2
A070 024C	StaticWaitRd2	Static Memory Read Delay 2
A070 0250	StaticWaitPage2	Static Memory Page Mode Read Delay 2
A070 0254	StaticWaitWr2	Static Memory Write Delay 2
A070 0258	StaticWaitTurn2	Static Memory Turn Round Delay 2
A070 0260	StaticConfig3	Static Memory Configuration Register 3
A070 0264	StaticWaitWen3	Static Memory Write Enable Delay 3
A070 0268	StaticWaitOen3	Static Memory Output Enable Delay 3
A070 026C	StaticWaitRd3	Static memory Read Delay 3
A070 0270	StaticWaitPage3	Static Memory Page Mode Read Delay 3
A070 0274	StaticWaitWr3	Static Memory Write Delay 3
A070 0278	StaticWaitTurn3	Static Memory Turn Round Delay 3

Table 177: Memory Controller register map

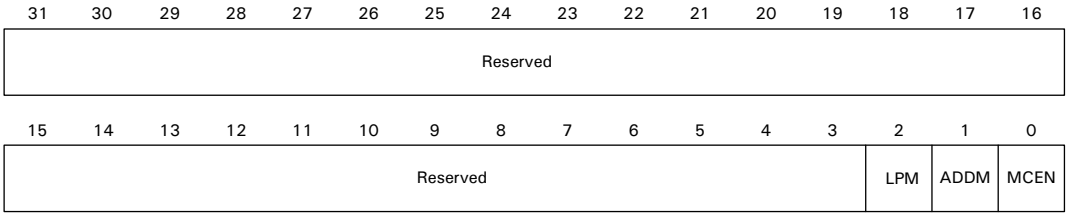
Reset values

Reset values will be noted as appropriate in the Description column of each register table, rather than as a separate column.

Control register

Address: A070 0000

The Control register controls the memory controller operation. The control bits can be changed during normal operation.



Register bit assignment

Bits	Access	Mnemonic	Description
D31:03	N/A	Reserved	N/A (do not modify)
D02	R/W	LPM	**Low-power mode** 0 Normal mode (reset value on `reset_n` and `HRESETn`) 1 Low-power mode Indicates normal or low-power mode. Entering low-power mode reduces memory controller power consumption. Dynamic memory is refreshed as necessary. The memory controller returns to normal functional mode by clearing the low-power mode bit, by AHB, or by power-on reset. If you modify this bit, be sure the memory controller is in idle state. If you modify the L bit, be aware of these conditions: ■ The external memory cannot be accessed in low-power or disabled state. If a memory access is performed in either of these states, an error response is generated. ■ The memory controller AHB programming port can be accessed normally. ■ The memory controller registers can be programmed in low-power and/or disabled state.

Table 178: Control register

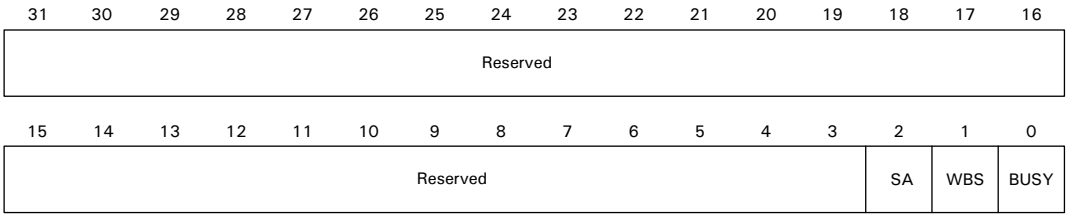
Bits	Access	Mnemonic	Description
D01	R/W	ADDM	**Address mirror** 0 Normal memory map 1 Reset memory map. Static memory chip select 1 is mirrored onto chip select 0 and chip select 4 (reset value on reset_n) Indicates normal or reset memory map. On power-on reset, chip select 1 is mirrored to both chip select 0 and chip select 4 memory areas. Clearing the M bit allows chip select 0 and chip select 4 memory to be accessed.
D00	R/W	MCEN	**Memory controller enable** 0 Disabled 1 Enabled (reset value on reset_n and HRESETn) Disabling the memory controller reduces power consumption. When the memory controller is disabled, the memory is not refreshed. The memory controller is enabled by setting the enable bit, by AHB, or by power-on reset. If you modify this bit, be sure the memory controller is in idle state. If you modify the E bit, be aware of these conditions: ■ The external memory cannot be accessed in low-power or disabled state. If a memory access is performed in either of these states, an error response is generated. ■ The memory controller AHB programming port can be accessed normally. ■ The memory controller registers can be programmed in low-power and/or disabled state.

Table 178: Control register

Status register

Address: A070 0004

The Status register provides memory controller status information.



Register bit assignment

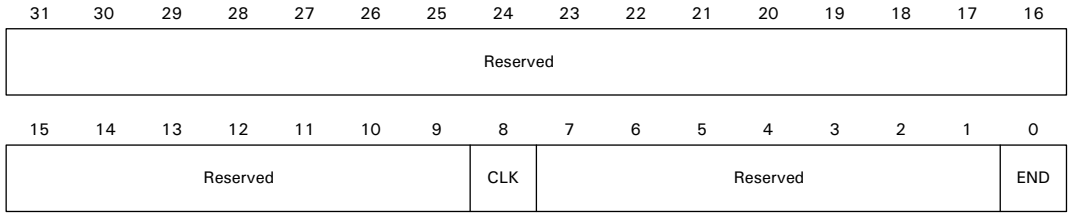
Bits	Access	Mnemonic	Description
D31:03	N/A	Reserved	N/A (do not modify)
D02	R	SA	**Self-refresh acknowledge (SREFACK)** 0 Normal mode 1 Self refresh mode (reset value on reset_n) Indicates the memory controller operating mode.
D01	R	WBS	**Write buffer status** 0 Write buffers empty (reset value on reset_n) 1 Write buffers contain data Enables the memory controller to enter low-power mode or disabled mode clearly.
D00	R	BUSY	**Busy** 0 Memory controller is idle (reset value on HRESETn) 1 Memory controller is busy performing memory transactions, commands, or auto-refresh cycles, or is in self-refresh mode (reset value on reset_n and HRESETn) Ensures that the memory controller enters the low-power or disabled state cleanly by determining whether the memory controller is busy.

Table 179: Status register

Configuration register

Address: A070 0008

The Configuration register configures memory controller operation. It is recommended that this register be modified during system initialization, or when there are no current or outstanding transactions. Wait until the memory controller is idle, then enter low-power or disabled mode.



Register bit assignment

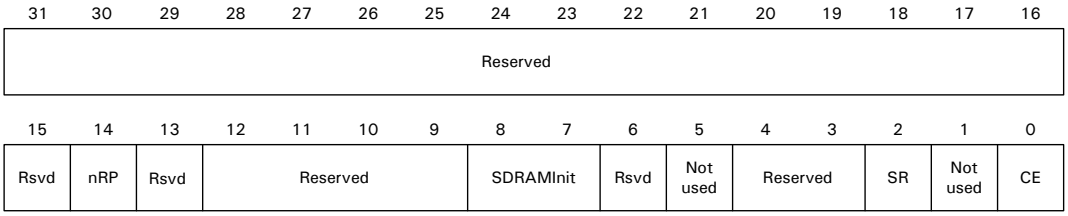
Bits	Access	Mnemonic	Description
D31:09	N/A	Reserved	N/A (do not modify)
D08	R/W	CLK	**Clock ratio (HCLK:clk-out[3:0]) ratio** 0 1:1 (reset value on reset_n) 1 1:2
D07:01	N/A	Reserved	N/A (do not modify)
D00	R/W	END	Endian mode 0 Little endian mode 1 Big endian mode The value of the endian bit on power-on reset (reset_n) is determined by the gpio[44] signal. This value can be overridden by software. This field is not affected by the AHB reset (HRESETn). **Note:** The value of the gpio[44] signal is reflected in this field. When programmed, this register reflects the last value written into the register. You must flush all data in the memory controller before switching between little endian and big endian modes.

Table 180: Configuration register

Dynamic Memory Control register

Address: A070 0020

The Dynamic Memory Control register controls dynamic memory operation. The control bits can be changed during normal operation.



Register bit assignment

Bits	Access	Mnemonic	Description
D31:15	N/A	Reserved	N/A (do not modify)
D14	R/W	nRP	**Sync/Flash reset/power down signal (**`dy_pwr_n`**)** 0 `dy_pwr_n` signal low (reset value on `reset_n`) 1 Set `dy_pwr_n` signal high
D13	R/W	Reserved	Must write 0.
D12:09	N/A	Reserved	N/A (do not modify)
D08:07	R/W	SDRAMInit	**SDRAM initialization** 00 Issue `SDRAM NORMAL` operation command (reset value on `reset_n`) 01 Issue `SDRAM MODE` command 10 Issue `SDRAM PALL` (precharge all) command 11 Issue `SDRAM NOP` (no operation) command
D06	N/A	Reserved	N/A (do not modify)
D05	R/W	Not used	Must write 0.
D04:03	N/A	Reserved	N/A (do not modify)

Table 181: Dynamic Memory Control register

Bits	Access	Mnemonic	Description
D02	R/W	SR	**Self-refresh request (**SREFREQ**)** 0 Normal mode 1 Enter self-refresh mode (reset value on reset_n) By writing 1 to this bit, self-refresh can be entered under software control. Writing 0 to this bit returns the memory controller to normal mode. The self-refresh acknowledge bit in the Status register (see page 280) must be polled to discover the current operating mode of the memory controller. **Note:** The memory controller exits from power-on reset with the self-refresh bit on high. To enter normal functional mode, set the self-refresh bit low. Writing to this register with the bit set to high places the register into self-refresh mode. This functionality allows data to be stored over SDRAM self-refresh of the ASIC is powered down.
D01	R/W	Not used	Must write 1.
D00	R/W	CE	**Dynamic memory clock enable** 0 Clock enable if idle devices are deasserted to save power (reset value on reset_n) 1 All clock enables are driven high continuously. **Note:** Clock enable must be high during SDRAM initialization.

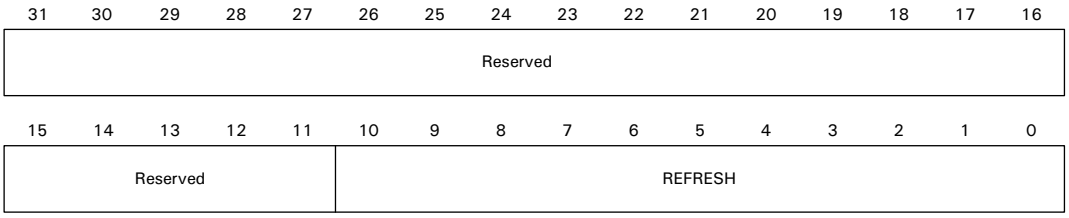
Table 181: Dynamic Memory Control register

Dynamic Memory Refresh Timer register

Address: A070 0024

The Dynamic Memory Refresh Timer register configures dynamic memory operation. It is recommended that this register be modified during system initialization, or when there are no current or outstanding transactions. Wait until the memory controller is idle, then enter low-power or disabled mode.These bits can, however, be changed during normal operation if necessary.

Note: The Dynamic Memory Refresh Timer register is used for all four dynamic memory chip selects. The worst case value for all chip selects must be programmed.



Register bit assignment

Bits	Access	Mnemonic	Description
D31:11	N/A	Reserved	N/A (do not modify)
D10:0	R/W	REFRESH	**Refresh timer** 0x0 Refresh disabled (reset value on reset_n) 0x1-0x77F n(x16) 16n HCLK ticks between SDRAM refresh cycles

Table 182: Dynamic Memory Refresh Timer register

Example

Generic formula: DynamicRefresh = (((t$_{REF}$ / #rows) * 200) / 32)
For 4k rows:

```
Refresh period = 64µs
Speed grade = 200 MHz
Calculation = ((64e-3 / 4096) * 200e+6) / 32 = 97 = 0x61
```

Notes:

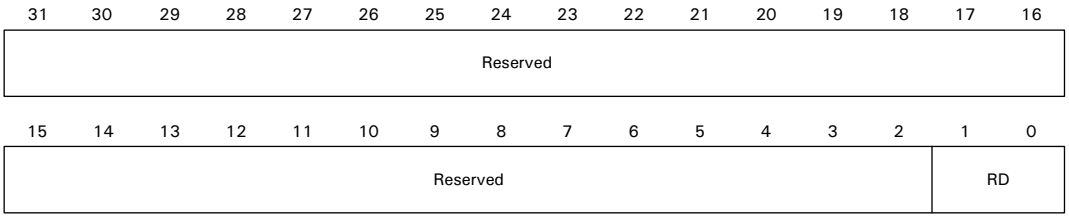
- The refresh cycles are evenly distributed. There might be slight variations, however, when the auto-refresh command is issued, depending on the status of the memory controller.
- Unlike other SDRAM memory timing parameters, the refresh period is programmed in the HCLK domain.

Dynamic Memory Read Configuration register

Address: A070 0028

The Dynamic Memory Read Configuration register allows you to configure the dynamic memory read strategy. Modify this register only during system initialization.

Note: The Dynamic Memory Read Configuration register is used for all four dynamic memory chip selects. The worst case value for all chip selects must be programmed.



Register bit assignment

Bits	Access	Mnemonic	Description
D31:02	N/A	Reserved	N/A (do not modify)
D01:00	RW	RD	**Read data strategy** 00 Reserved. 01 Command delayed strategy, using CLKDELAY (command delayed, clock out not delayed). 10 Command delayed strategy plus one clock cycle, using CLKDELAY (command delayed, clock out not delayed). 11 Command delayed strategy plus two clock cycles, using CLKDELAY (command delayed, clock out not delayed).

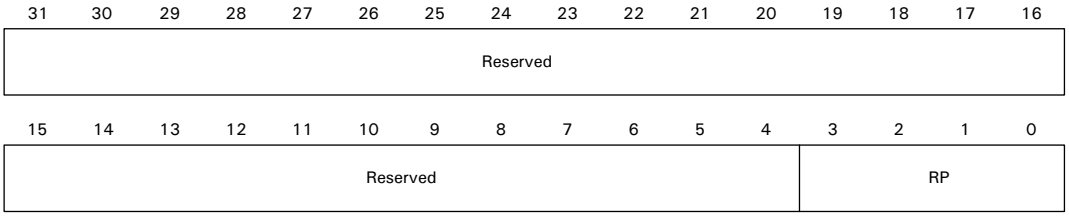
Table 183: Dynamic Memory Read Configuration register

Dynamic Memory Precharge Command Period register

Address: A070 0030

The Dynamic Memory Precharge Command Period register allows you to program the precharge command period, t_{RP}. Modify this register only during system initialization. This value normally is found in SDRAM datasheets as t_{RP}.

Note: The Dynamic Memory Precharge Command Period register is used for all four dynamic memory chip selects. The worst case value for all chip selects must be programmed.



Register bit assignment

Bits	Access	Mnemonic	Description
D31:04	N/A	Reserved	N/A (do not modify)
D03:00	R/W	RP	**Precharge command period (t_{RP})** 0x0-0xE n + 1 clock cycles, where the delay is in CLK cycles. ØxF 16 clock cycles (reset value on reset_n)

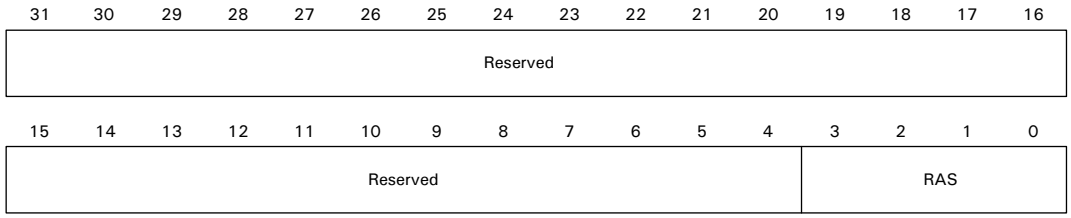
Table 184: Dynamic Memory Precharge Command Period register

Dynamic Memory Active to Precharge Command Period register

Address: A070 0034

The Dynamic Memory Active to Precharge Command Period register allows you to program the active to precharge command period, t_{RAS}. It is recommended that this register be modified during system initialization, or when there are no current or outstanding transactions. Wait until the memory controller is idle, then enter low-power or disabled mode. This value normally is found in SDRAM datasheets as t_{RAS}.

Note: The Dynamic Memory Active to Precharge Command Period register is used for all four dynamic memory chip selects. The worst case value for all chip selects must be programmed.



Register bit assignment

Bits	Access	Mnemonic	Description
D31:04	N/A	Reserved	N/A (do not modify)
D03:00	R/W	RAS	**Active to precharge command period (t_{RAS})** 0x0-0xE n + 1 clock cycles, where the delay is in CLK cycles. ØxF 16 clock cycles (reset value on reset_n)

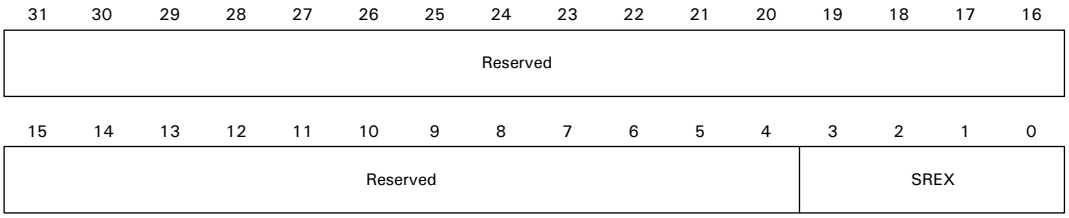
Table 185: Dynamic Memory Active to Precharge Command Period register

Dynamic Memory Self-refresh Exit Time register

Address: A070 0038

The Dynamic Memory Self-refresh Exit Time register allows you to program the self-refresh exit time, t_{SREX}. It is recommended that this register be modified during system initialization, or when there are no current or outstanding transactions. Wait until the memory controller is idle, then enter low-power or disabled mode. This value normally is found in SDRAM data sheets as t_{SREX}.

Note: The Dynamic Memory Self-refresh Exit Time register is used for all four dynamic memory chip selects. The worst case value for all chip selects must be programmed.



Register bit assignment

Bits	Access	Mnemonic	Description
D31:04	N/A	Reserved	N/A (do not modify)
D03:00	R/W	SREX	**Self-refresh exit time (t_{SREX})** 0x0-0xE n + 1 clock cycles, where the delay is in CLK cycles. ØxF 16 clock cycles (reset value on reset_n)

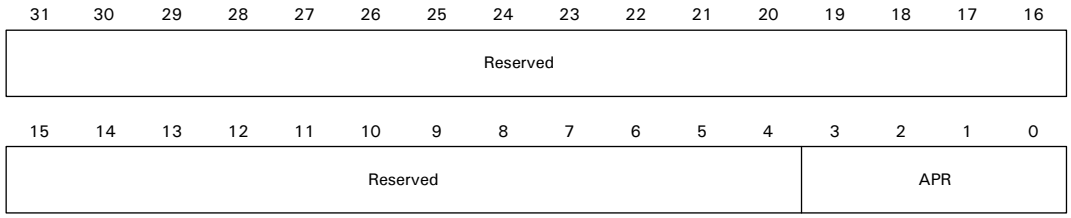
Table 186: Dynamic Memory Self-refresh Exit Time register

Dynamic Memory Last Data Out to Active Time register

Address: A070 003C

The Dynamic Memory Last Data Out to Active Time register allows you to program the last-data-out to active command time, t_{APR}. It is recommended that this register be modified during system initialization, or when there are no current or outstanding transactions. Wait until the memory controller is idle, then enter low-power or disabled mode. This value normally is found in SDRAM datasheets as t_{APR}.

Note: The Dynamic Memory Last Data Out to Active Time register is used for all four dynamic memory chip selects. The worst case value for all chip selects must be programmed.



Register bit assignment

Bits	Access	Mnemonic	Description
D31:04	N/A	Reserved	N/A (do not modify)
D03:00	R/W	APR	**Last-data-out to active command time (t_{APR})** 0x0-0xE n + 1 clock cycles, where the delay is in CLK cycles. ØxF 16 clock cycles (reset value on reset_n)

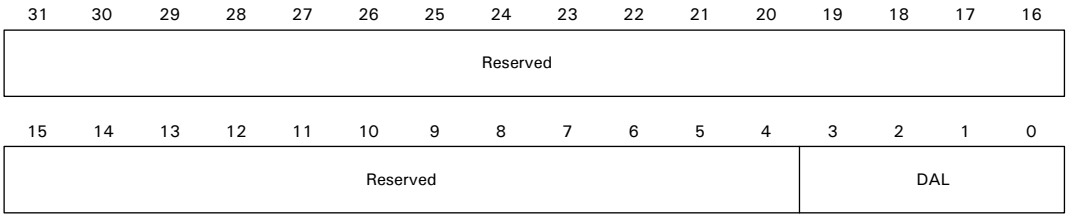
Table 187: Dynamic Memory Last Data Out to Active Time register

Dynamic Memory Data-in to Active Command Time register

Address: A070 0040

The Dynamic Memory Data-in to Active Command Time register allows you to program the data-in to active command time, t_{DAL}. It is recommended that this register be modified during system initialization, or when there are no current or outstanding transactions. Wait until the memory controller is idle, then enter low-power or disabled mode. This value normally is found in SDRAM data sheets as t_{DAL} or t_{APW}.

Note: The Dynamic Memory Data-in Active Command Time register is used for all four dynamic memory chip selects. The worst case value for all chip selects must be programmed.



Register bit assignment

Bits	Access	Mnemonic	Description
D31:04	N/A	Reserved	N/A (do not modify)
D03:00	R/W	DAL	**Data-in to active command (t_{DAL} or t_{APW})** 0x0-0xE n + 1 clock cycles, where the delay is in CLK cycles. ØxF 15 clock cycles (reset value on reset_n)

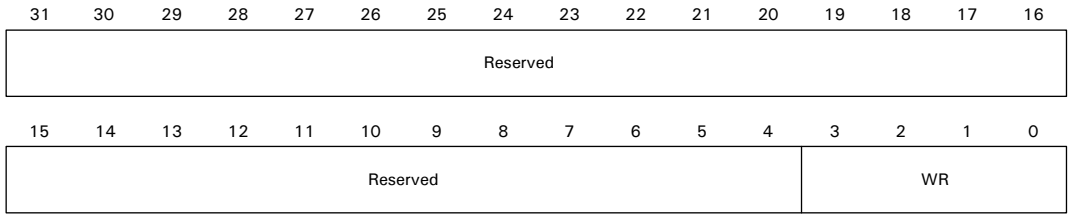
Table 188: Dynamic Memory Data-in Active Command Time register

Dynamic Memory Write Recovery Time register

Address: A070 0044

The Dynamic Memory Write Recovery Time register allows you to program the write recovery time, t_{WR}. It is recommended that this register be modified during system initialization, or when there are no current or outstanding transactions. Wait until the memory controller is idle, then enter low-power or disabled mode. This value normally is found in SDRAM datasheets as t_{WR}, t_{DPL}, t_{RWL}, or t_{RDL}.

Note: The Dynamic Memory Write Recovery Time register is used for all four dynamic memory chip selects. The worst case value for all chip selects must be programmed.



Register bit assignment

Bits	Access	Mnemonic	Description
D31:04	N/A	Reserved	N/A (do not modify)
D03:00	R/W	WR	Write recovery time (t_{WR}, t_{DPL}, t_{RWL}, or t_{RDL}) 0x0-0xE n + 1 clock cycles, where the delay is in CLK cycles. ØxF 16 clock cycles (reset value on reset_n)

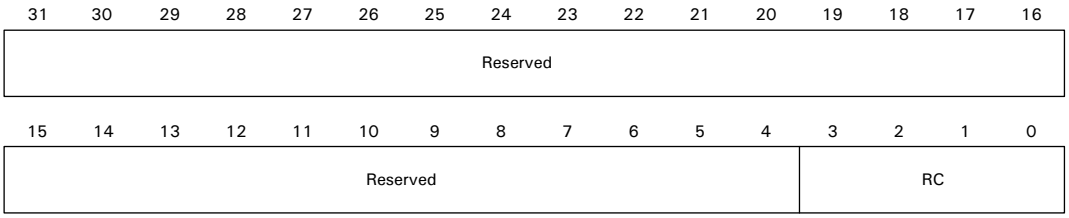
Table 189: Dynamic Memory Write Recovery TIme register

Dynamic Memory Active to Active Command Period register

Address: A070 0048

The Dynamic Memory Active to Active Command Period register allows you to program the active to active command period, t_{RC}. It is recommended that this register be modified during system initialization, or when there are no current or outstanding transactions. Wait until the memory controller is idle, then enter low-power or disabled mode. This value normally is found in SDRAM datasheets as t_{RC}.

Note: The Dynamic Memory Active to Active Command period register is used for all four dynamic memory chip selects. The worst case value for all chip selects must be programmed.



Register bit assignment

Bits	Access	Mnemonic	Description
D31:05	N/A	Reserved	N/A (do not modify)
D04:00	R/W	RC	**Active to active command period (t_{RC})** 0x0-0x1E n + 1 clock cycles, where the delay is in CLK cycles. Ø1F 32 clock cycles (reset value on reset_n)

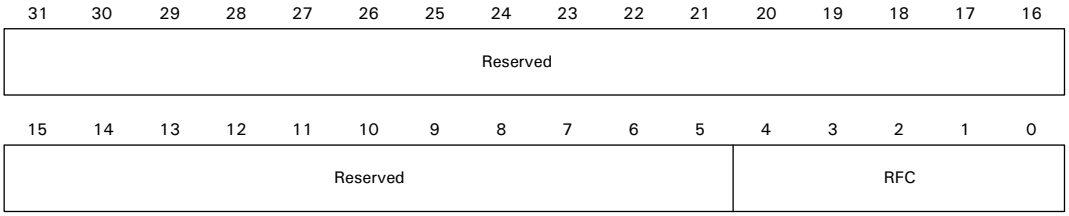
Table 190: Dynamic Memory Active to Active Command Period register

Dynamic Memory Auto Refresh Period register

Address: A070 004C

The Dynamic Memory Auto Refresh Period register allows you to program the auto-refresh period and the auto-refresh to active command period, t_{RFC}. It is recommended that this register be modified during initialization, or when there are no current or outstanding transactions. Wait until the memory controller is idle, then enter low-power or disabled mode. This value normally is found in SDRAM datasheets as t_{RFC} or t_{RC}.

Note: The Dynamic Memory Auto Refresh Period register is used for all four dynamic memory chip selects. The worst case value for all chip selects must be programmed.



Register bit assignment

Bits	Access	Mnemonic	Description
D31:05	N/A	Reserved	N/A (do not modify)
D04:00	R/W	RFC	**Auto-refresh period and auto-refresh to active command period** 0x0-0x1E n + 1 clock cycles, where the delay is in CLK cycles. Ø1F 32 clock cycles (reset value on reset_n)

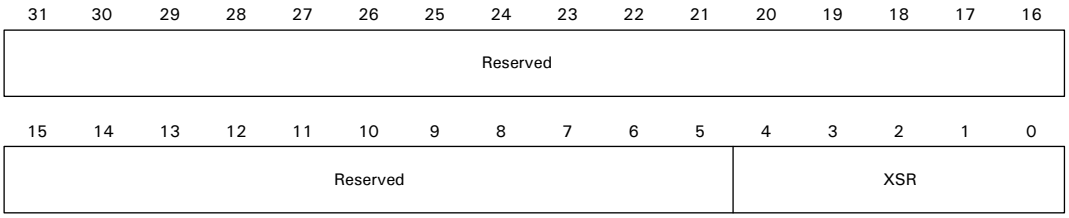
Table 191: Dynamic Memory Auto Refresh Period register

Dynamic Memory Exit Self-refresh register

Address: A070 0050

The Dynamic memory Exit Self-refresh register allows you to program the exit self-refresh to active command time, t_{XSR}. It is recommended that this register be modified during system initialization, or when there are no current or outstanding transactions. Wait until the memory controller is idle, then enter low-power or disabled mode. This value normally is found in SDRAM datasheets as t_{XSR}.

Note: The Dynamic Memory Exit Self-refresh register is used for all four dynamic memory chip selects. The worst case value for all the chip selects must be programmed.



Register bit assignment

Bits	Access	Mnemonic	Description
D31:05	N/A	Reserved	N/A (do not modify)
D04:00	R/W	XSR	**Exit self-refresh to active time command** 0x0-0x1E n + 1 clock cycles, where the delay is in CLK cycles. Øx1F 32 clock cycles (reset value on reset_n)

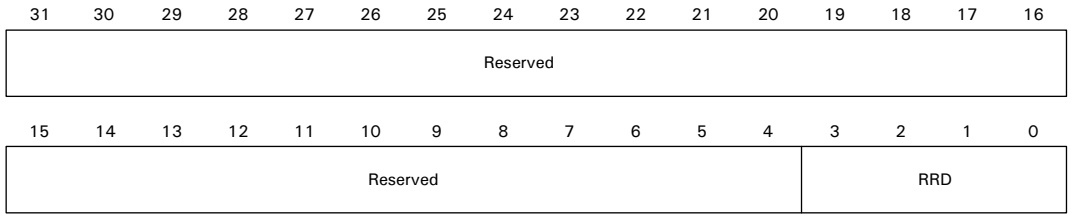
Table 192: Dynamic Memory Exit Self-refresh register

Dynamic Memory Active Bank A to Active Bank B Time register

Address: A070 0054

The Dynamic Memory Active Bank A to Active Bank B Time register allows you to program the active bank A to active bank B latency, t_{RRD}. It is recommended that this register be modified during system initialization, or when there are no current or outstanding transactions. Wait until the memory controller is idle, then enter low-power or disabled mode. This value normally is found in SDRAM datasheets as t_{RRD}.

Note: The Dynamic Memory Active Bank A to Active Bank B Time register is used for all four dynamic memory chip selects. The worst case value for all chip selects must be programmed.



Register bit assignment

Bits	Access	Mnemonic	Description
D31:04	N/A	Reserved	N/A (do not modify)
D03:00	R/W	RRD	**Active bank A to Active bank B latency** 0x0-0xE n + 1 clock cycles, where the delay is in CLK cycles 0xF 16 clock cycles (reset on reset_n)

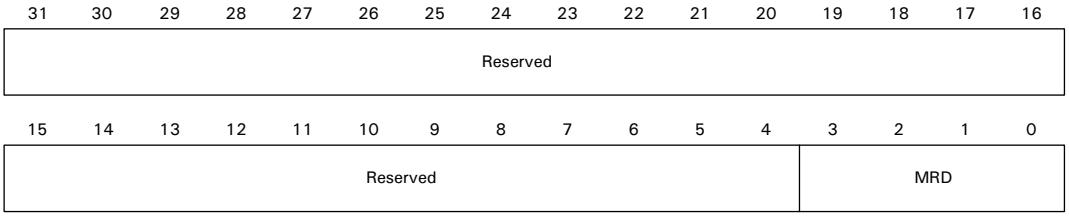
Table 193: Dynamic Memory Active Bank A to Active Bank B Time register

Dynamic Memory Load Mode register to Active Command Time register

Address: A070 0058

The Dynamic Memory Load Mode register to Active Command Time register allows you to program the Load Mode register to active command time, t_{MRD}. It is recommended that this register be modified during system initialization, or when there are no current or outstanding transactions. Wait until the memory controller is idle, then enter low-power or disabled mode. This value normally is found in SDRAM datasheets as t_{MRD} or t_{RSA}.

Note: The Dynamic Memory Load Mode register to Active Command Time register is used for all four chip selects. The worst case value for all chip selects must be programmed.



Register bit assignment

Bits	Access	Mnemonic	Description
D31:04	N/A	Reserved	N/A (do not modify)
D03:00	R/W	MRD	**Load Mode register to active command time** 0x0-0xE n + 1 clock cycles, where the delay is in CLK cycles 0xF 16 clock cycles (reset on reset_n)

Table 194: Dynamic Memory Load Mode register to Active Command Time register

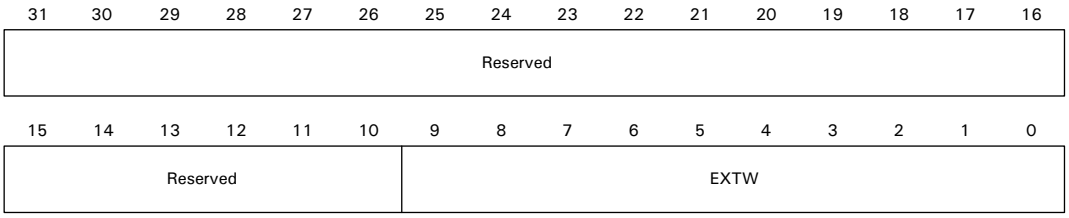
Static Memory Extended Wait register

Address: A070 0080

The Static Memory Extended Wait register times long static memory read and write transfers (which are longer than can be supported by the Static Memory Read Delay registers (see page 309) or the Static Memory Write Delay registers (see page 311)) when the EW (extended wait) bit in the related Static Memory Configuration register (see page 303) is enabled.

There is only one Static Memory Extended Wait register, which is used by the relevant static memory chip select if the appropriate EW bit is set in the Static Memory Configuration register.

It is recommended that this register be modified during system initialization, or when there are no current or outstanding transactions. If necessary, however, these control bits can be changed during normal operation.



Register bit assignment

Bits	Access	Mnemonic	Description
D31:10	N/A	Reserved	N/A (do not modify)
D09:00	R/W	EXTW	**External wait timeout** 0x0 16 clock cycles, where the delay is in HCLK cycles 0x1-0x3FF (n = 1) x16 clock cycles

Table 195: Static Memory Extended Wait register

Example

Static memory read/write time = 16 ms

CLK frequency = 50 MHz

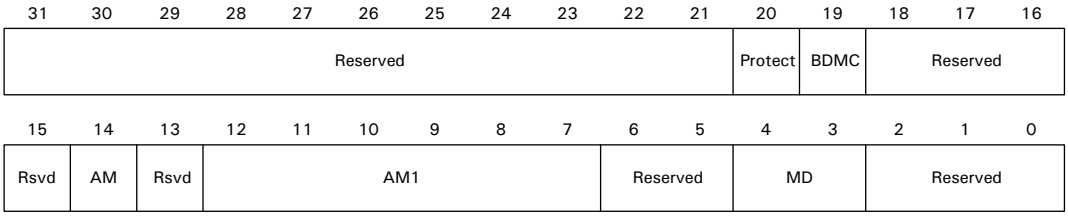
This value must be programmed into the Static Memory Extended Wait register:

$(16 \times 10^{-6} \times 50 \times 10^{6} / 16) - 1 = 49$

Dynamic Memory Configuration 0–3 registers

Address: A070 0100 / 0120 / 0140 / 0160

The Dynamic Memory Configuration 0–3 registers allow you to program the configuration information for the relevant dynamic memory chip select. These registers are usually modified only during system initialization.



Register bit assignment

Bits	Access	Mnemonic	Description
D31:21	N/A	Reserved	N/A (do not modify)
D20	R/W	Protect	**Write protect** 0 Writes not protected (reset value on reset_n) 1 Write protected
D19	R/W	BDMC	**Buffer enable** 0 Buffer disabled for accesses to this chip select (reset value on reset_n) 1 Buffer enabled for accesses to this chip select. The buffers must be disabled during SDRAM initialization. The buffers must be enabled during normal operation.
D18:15	N/A	Reserved	N/A (do not modify)

Table 196: Dynamic Memory Configuration 0–3 registers

Bits	Access	Mnemonic	Description
D14	R/W	AM	**Address mapping** 0 Reset value on reset_n See Table 197, "Address mapping," on page 299 for more information.
D13	N/A	Reserved	N/A (do not modify)
D12:07	R/W	AM1	**Address mapping** 00000000 Reset value on reset_n The SDRAM column and row width and number of banks are computed automatically from the address mapping. See Table 197, "Address mapping," on page 299 for more information.
D06:05	N/A	Reserved	N/A (do not modify)
D04:03	R/W	MD	**Memory device** 00 SDRAM (reset value on reset_n) 01 Low-power SDRAM 10 Reserved 11 Reserved
D02:00	N/A	Reserved	N/A (do not modify)

Table 196: Dynamic Memory Configuration 0–3 registers

Table 197 shows address mapping for the Dynamic Memory Configuration 0-3 registers. Address mappings that are not shown in the table are reserved.

[14]	[12]	[11:9]	[8:7]	Description
16-bit external bus high-performance address mapping (row, bank column)				
0	0	000	00	16 Mb (2Mx8), 2 banks, row length = 11, column length = 9
0	0	000	01	16 Mb (1Mx16), 2 banks, row length = 11, column length = 8
0	0	001	00	64 Mb (8Mx80, 4 banks, row length = 12, column length = 9
0	0	001	01	64 Mb (4Mx16), 4 banks, row length = 12, column length = 8
0	0	010	00	128 Mb (16Mx8), 4 banks, row length = 12, column length = 10
0	0	010	01	128 Mb (8Mx16), 4 banks, row length = 12, column length = 9

Table 197: Address mapping

[14]	[12]	[11:9]	[8:7]	Description
0	0	011	00	256 Mb (32Mx8), 4 banks, row length = 13, column length = 10
0	0	011	01	256 Mb (16Mx16), 4 banks, row length = 13, column length = 9
0	0	100	00	512 Mb (64Mx8), 4 banks, row length = 13, column length = 11
0	0	100	01	512 Mb (32Mx16), 4 banks, row length = 13, column length = 10
16-bit external bus low-power SDRAM address mapping (bank, row, column)				
0	1	000	00	16 Mb (2Mx8), 2 banks, row length = 11, column length = 9
0	1	000	01	16 Mb (1Mx16), 2 banks, row length = 11, column length = 8
0	1	001	00	64 Mb (8Mx8), 4 banks, row length 12, column length = 9
0	1	001	01	64 Mb (4Mx16), 4 banks, row length = 12, column length = 8
0	1	010	00	128 Mb (16Mx8), 4 banks, row length = 12, column length = 10
0	1	010	01	128 Mb (8Mx16), 4 banks, row length = 12, column length = 9
0	1	011	00	256 Mb (32Mx8), 4 banks, row length = 13, column length = 10
0	1	011	01	256 Mb (16Mx16), 4 banks, row length = 13, column length = 9
0	1	100	00	512 Mb (64Mx8), 4 banks, row length = 13, column length = 11
0	1	100	01	512 Mb (32Mx16, 4 banks, row length = 13, column length = 10
32-bit extended bus high-performance address mapping (row, bank, column)				
1	0	000	00	16 Mb (2Mx8), 2 banks, row length = 11, column length = 9
1	0	000	01	16 Mb (1Mx16), 2 banks, row length = 11, column length = 8
1	0	001	00	64 Mb (8Mx8), 4 banks, row length = 12, column length = 9
1	0	001	01	64 Mb (4Mx16), 4 banks, row length = 12, column length = 8
1	0	001	10	64 Mb (2Mx32), 4 banks, row length = 11, column length = 8
1	0	010	00	128 Mb (16Mx8), 4 banks, row length = 12, column length = 10
1	0	010	01	128 Mb (8Mx16), 4 banks, row length = 12, column length = 9
1	0	010	10	128 Mb (4Mx32), 4 banks, row length = 12, column length = 8
1	0	011	00	256 Mb (32Mx8), 4 banks, row length = 13, column length = 10
1	0	011	01	256 Mb (16Mx16), 4 banks, row length = 13, column length = 9
1	0	011	10	256 Mb (8Mx32), 4 banks, row length = 13, column length = 8

Table 197: Address mapping

[14]	[12]	[11:9]	[8:7]	Description
1	0	100	00	512 Mb (64Mx8), 4 banks, row length = 13, column length = 11
1	0	100	01	512 Mb (32Mx16), 4 banks, row length = 13, column length = 10
32-bit extended bus low-power SDRAM address mapping (bank, row, column)				
1	1	000	00	16 Mb (2Mx8), 2 banks, row length = 11, column length = 9
1	1	000	01	16 Mb (1Mx16), 2 banks, row length = 11, column length = 8
1	1	001	00	64 Mb (8Mx8), 4 banks, row length = 12, column length = 9
1	1	001	01	64 MB (4Mx16), 4 banks, row length = 12, column length = 8
1	1	001	10	64 Mb (2Mx32), 4 banks, row length = 11, column length = 8
1	1	010	00	128 Mb (16Mx8), 4 banks, row length = 12, column length = 10
1	1	010	01	128 Mb (8Mx16), 4 banks, row length = 12, column length = 9
1	1	010	10	128 Mb (4Mx32), 4 banks, row length = 12, column length = 8
1	1	011	00	256 Mb (32Mx8), 4 banks, row length = 13, column length = 10
1	1	011	01	256 Mb (16Mx16), 4 banks, row length = 13, column length = 9
1	1	011	10	256 Mb (8Mx32), 4 banks, row length = 13, column length = 8
1	1	100	00	512 Mb (64Mx8), 4 banks, row length = 13, column length = 11
1	1	100	01	512 Mb (32Mx16), 4 banks, row length = 13, column length = 10

Table 197: Address mapping

A chip select can be connected to a single memory device; in this situation, the chip select data bus width is the same as the device width. As an alternative, the chip select can be connected to a number of external devices. In this situation, the chip select data bus width is the sum of the memory device databus widths.

Examples

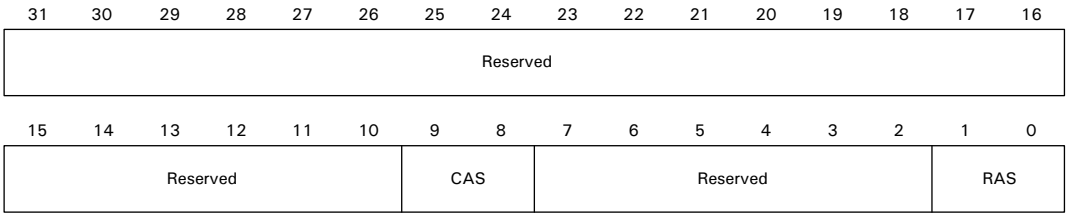
For a chip select connected to	Select this mapping
32-bit wide memory device	32-bit wide address mapping
16-bit wide memory device	16-bit wide address mapping
4 x 8-bit wide memory devices	32-bit wide address mapping
2 x 8-bit memory devices	16-bit wide address mapping

Dynamic Memory RAS and CAS Delay 0–3 registers

Address: A070 0104 / 0124 / 0144 / 0164

The Dynamic Memory RAS and CAS Delay 0–3 registers allow you to program the RAS and CAS latencies for the relevant dynamic memory. It is recommended that these registers be modified during system initialization, or when there are no current or outstanding transactions. Wait until the memory controller is idle, then enter low-power or disabled mode.

Note: The values programmed into these registers must be consistent with the values used to initialize the SDRAM memory device.



Register bit assignment

Bits	Access	Mnemonic	Description
D31:10	N/A	Reserved	N/A (do not modify)
D09:08	R/W	CAS	**CAS latency** 00 Reserved 01 One clock cycle, where the RAS to CAS latency (RAS) and CAS latency (CAS) are defined in CLK cycles 10 Two clock cycles 11 Three clock cycles (reset value on `reset_n`)
D07:02	N/A	Reserved	N/A (do not modify)

Table 198: Dynamic Memory RAS and CAS Delay 0–3 registers

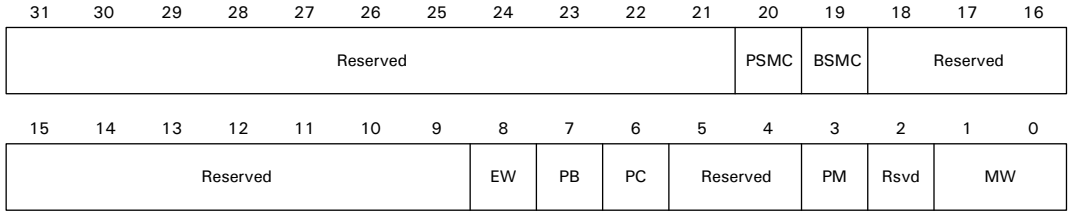
Bits	Access	Mnemonic	Description
D01:00	R/W	RAS	**RAS latency (active to read.write delay)** 00 Reserved 01 One clock cycle, where the RAS to CAS latency (RAS) and CAS latency (CAS) are defined in CLK cycles 10 Two clock cycles 11 Three clock cycles (reset value on reset_n)

Table 198: Dynamic Memory RAS and CAS Delay 0–3 registers

Static Memory Configuration 0–3 registers

Address: A070 0200 / 0220 / 0240 / 0260

The Static Memory Configuration 0–3 registers configure the static memory configuration. It is recommended that these registers be modified during system initialization, or when there are no current or outstanding transactions. Wait until the memory controller is idle, then enter low-power or disabled mode.



Register bit assignment

Bits	Access	Mnemonic	Description
D31:21	N/A	Reserved	N/A (do not modify)
D20	R/W	PSMC	**Write protect** 0 Writes not protected (reset value on reset_n) 1 Write protected

Table 199: Static Memory Configuration 0–3 registers

Bits	Access	Mnemonic	Description
D19	R/W	BSMC	**Buffer enable** 0 Write buffer disabled (reset value on reset_n) 1 Write buffer enabled **Note:** This field must always be set to 0 when a peripheral other than SRAM is attached to the static ram chip select.
D18:09	N/A	Reserved	N/A (do not modify)
D08	R/W	EW	**Extended wait** 0 Extended wait disabled (reset value on reset_n) Extended wait enabled Extended wait uses the Static Extended Wait register (see page 297) to time both the read and write transfers, rather than the Static Memory Read Delay 0–3 registers (see page 309) and Static Memory Write Delay 0–3 registers (see page 311). This allows much longer transactions. Extended wait also can be used with the ta_strb signal to allow a slow peripheral to terminate the access. In this case, the Static Memory Extended Wait register (see page 297) can be programmed with the maximum timeout limit. A high value on ta_strb is then used to terminate the access before the maximum timeout occurs. **Note:** Extended wait and page mode cannot be selected simultaneously.

Table 199: Static Memory Configuration 0–3 registers

Bits	Access	Mnemonic	Description
D07	R/W	PB	**Byte lane state** 0 For reads, all bits in byte_lane_sel_n[3:0] are high. For writes, the respective active bits in byte_lane_sel_n[3:0] are low (reset value for chip select 0, 2, and 3 on reset_n). 1 For reads, the respective active bits in byte_lane_sel_n[3:0] are low. For writes, the respective active bits in byte_lane_sel_n[3:0] are low. **Note:** Setting this bit to 0 disables the write enable signal. WE_n will always be set to 1 (that is, you must use byte lane select signals). The value of the chip select 1 byte lane state field on power-on reset (reset_n) is determined by the boot_strap[0] signal. This value can be overridden by software. This field is not affected by AHB reset (HRESETn). The byte lane state bit (PB) enables different types of memory to be connected. For byte-wide static memories, the byte_lane_sel_n[3:0] signal from the memory controller is usually connected to WE_n (write enable). In this case, for reads, all byte_lane_sel_n[3:0] bits must be high, which means that the byte lane state bit must be low. 16-bit wide static memory devices usually have the byte_lane_sel_n[3:0] signals connected to the nUB and nLB (upper byte and lower byte) signals in the static memory. In this case, a write to a particular byte must assert the appropriate nUB or nLB signal low. For reads, all nUB and nLB signals must be asserted low so the bus is driven. In this case, the byte lane state must be high. **Note:** For chip select 1, the value of the boot-strap[0] signal is reflected in this field. When programmed, this register reflects the last value written into it.
D06	R/W	PC	**Chip select polarity** 0 Active low chip select 1 Active high chip select The value of the chip select polarity on power-on reset (reset_n) for chip select 1 is determined by the gpio[49] signal. This value can be overridden by software. This field is not affected by AHB reset (HRESETn).

Table 199: Static Memory Configuration 0–3 registers

Bits	Access	Mnemonic	Description
D05:04	N/A	Reserved	N/A (do not modify)
D03	R/W	PM	**Page mode** 0 Disabled (reset on reset_n) 1 Async page mode enabled (page length four) In page mode, the memory controller can burst up to four external accesses. Devices with asynchronous page mode burst four or higher are supported. Asynchronous page mode burst two devices are not supported and must be accessed normally.
D02	N/A	Reserved	N/A (do not modify)
D01:00	R/W	MW	**Memory width** 00 8 bit (reset value for chip select 0, 2, and 3 on reset_n) 01 16 bit 10 32 bit 11 Reserved The value of the chip select 1 memory width field on power-on reset (reset_n) is determined by the boot_strap[4:3] signal. This value can be overridden by software. This field is not affected by AHB reset (HRESETn). **Note:** For chip select 1, the value of the boot_strap[4:3] signal is reflected in this field. When programmed, this register reflects the last value written into it.

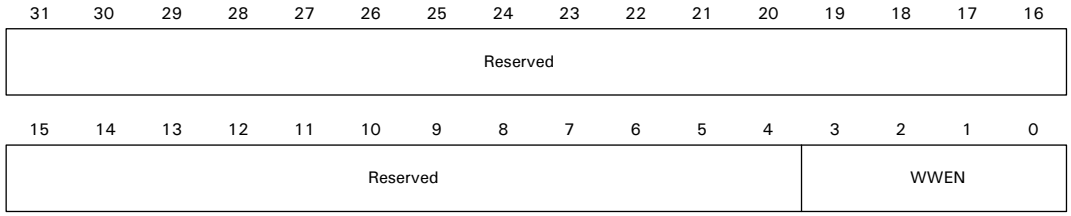
Table 199: Static Memory Configuration 0–3 registers

Note: Synchronous burst mode memory devices are not supported.

Static Memory Write Enable Delay 0–3 registers

Address: A070 0204 / 0224 / 0244 / 0264

The Static Memory Write Enable Delay 0–3 registers allow you to program the delay from the chip select to the write enable assertion. The Static Memory Write Enable Delay register is used in conjunction with the Static Memory Write Delay registers, to control the width of the write enable signals. It is recommended that these registers be modified during system initialization, or when there are no current or outstanding transactions. Wait until the memory controller is idle, then enter low-power or disabled mode.



Register bit assignment

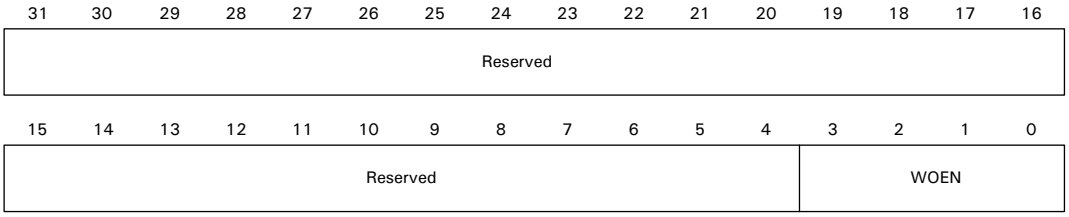
Bits	Access	Mnemonic	Description
D31:04	N/A	Reserved	N/A (do not modify)
D03:00	R/W	WWEN	**Wait write enable (WAITWEN)** 0000 One HCLK cycle delay between assertion of chip select and write enable (reset value on reset_n). 0001–1111 (n + 1) HCLK cycle delay, where the delay is (WAITWEN + 1) x t_{HCLK} Delay from chip select assertion to write enable.

Table 200: Static Memory Write Enable Delay 0–3 registers

Static Memory Output Enable Delay 0–3 registers

Address: A070 0208 / 0228 / 0248 / 0268

The Static Memory Output Enable Delay 0–3 registers allow you to program the delay from the chip select or address change, whichever is later, to the output enable assertion. The Static Memory Output Enable Delay register is used in conjunction with the Static Memory Read Delay registers, to control the width of the output enable signals. It is recommended that these registers be modified during system initialization, or when there are no current or outstanding transactions. Wait until the memory controller is idle, then enter low-power or disabled mode.



Register bit assignment

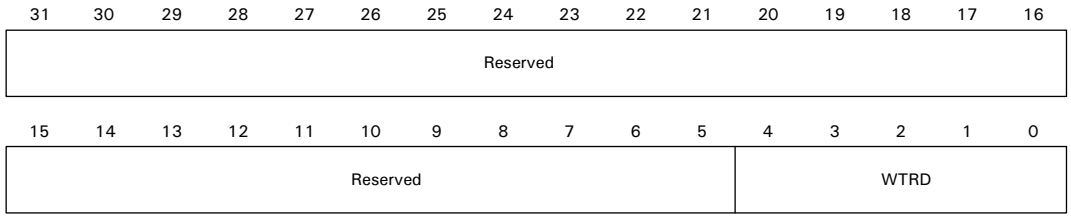
Bits	Access	Mnemonic	Description
D31:04	N/A	Reserved	N/A (do not modify)
D03:00	R/W	WOEN	**Wait output enable (WAITOEN)** 0000 No delay (reset value on reset_n). 0001–1111 n cycle delay, where the delay is WAITOEN x t_{HCLK} Delay from chip select assertion to output enable.

Table 201: Static Memory Output Enable Delay 0–3 registers

Static Memory Read Delay 0–3 registers

Address: A070 020C / 022C / 024C / 026C

The Static Memory Read Delay 0–3 registers allow you to program the delay from the chip select to the read access. It is recommended that these registers be modified during system initialization, or when there are no current or outstanding transactions. Wait until the memory controller is idle, then enter low-power or disabled mode. These registers are not used if the extended wait bit is set in the related Static Memory Configuration register (see page 303).



Register bit assignment

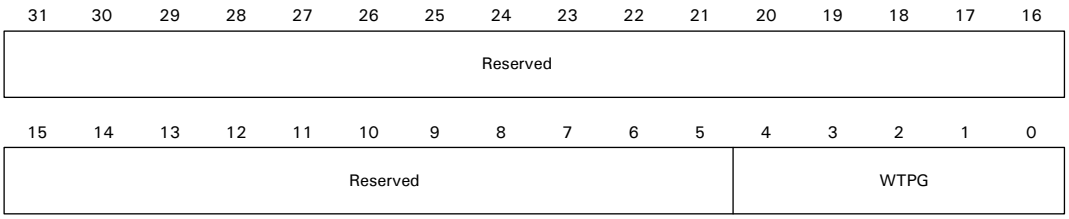
Bits	Access	Mnemonic	Description
D31:05	N/A	Reserved	N/A (do not modify)
D04:00	R/W	WTRD	Nonpage mode read wait states or asynchronous page mode read first access wait state (WAITRD) 00000–11110 (n + 1) HCLK cycle for read accesses. For nonsequential reads, the wait state time is (WAITRD + 1) x t_{HCLK} 11111 32 HCLK cycles for read accesses (reset value on reset_n) Use this equation to compute this field: WTRD = ([T_b + T_a + 10.0] / T_c) - 1 T_b = Total board propagation delay, including any buffers T_a = Peripheral access time T_c = AHB clock period. This is equal to twice the CPU clock period. Any decimal portion must be rounded up. All values are in nanoseconds.

Table 202: Static Memory Read Delay 0–3 registers

Static Memory Page Mode Read Delay 0–3 registers

Address: A070 0210 / 0230 / 0250 / 0270

The Static Memory Page Mode Read Delay 0–3 registers allow you to program the delay for asynchronous page mode sequential accesses. These registers control the overall period for the read cycle. It is recommended that these registers be modified during system initialization, or when there are no current or outstanding transactions. Wait until the memory controller is idle, then enter low-power or disabled mode.



Register bit assignment

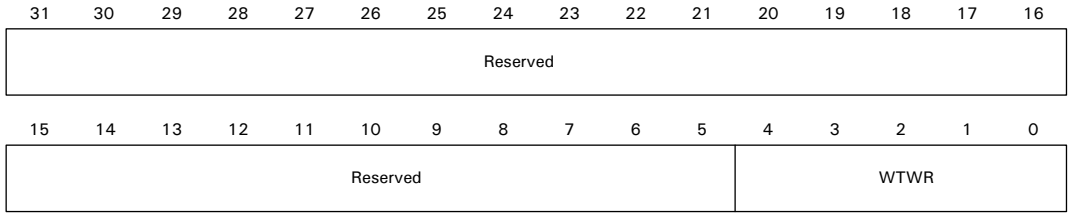
Bits	Access	Mnemonic	Description
D31:05	N/A	Reserved	N/A (do not modify)
D04:00	R/W	WTPG	**Asynchronous page mode read after the first wait state (WAITPAGE)** 00000–11110 (n + 1) HCLK cycle for read access time. For asynchronous page mode read for sequential reads, the wait state time for page mode accesses after the first read is (WAITPAGE + 1) x t_{HCLK} 11111 32 HCLK cycles read access time (reset value on `reset_n`) Number of wait states for asynchronous page mode read accesses after the first read.

Table 203: Static Memory Page Mode Read Delay 0–3 registers

Static Memory Write Delay 0–3 registers

Address: A070 0214 / 0234 / 0254 / 0274

The Static Memory Write Delay 0–3 registers allow you to program the delay from the chip select to the write access. These registers control the overall period for the write cycle. It is recommended that these registers be modified during system initialization, or when there are no current or outstanding transactions. Wait until the memory controller is idle, then enter low-power or disabled mode.These registers are not used if the extended wait bit is enabled in the related Static Memory Configuration register (see page 303).



Register bit assignment

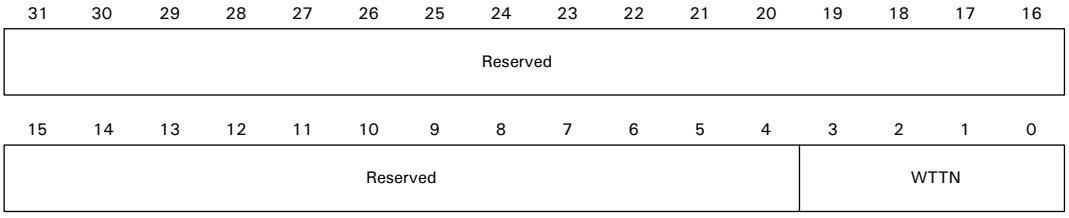
Bits	Access	Mnemonic	Description
D31:05	N/A	Reserved	N/A (do not modify)
D04:00	R/W	WTWR	**Write wait states (WAITWR)** 00000–11110 (n + 2) HCLK cycle write access time. The wait state time for write accesses after the first read is WAITWR (n + 2) x t_{HCLK} 11111 332 HCLK cycle write access time (reset value on reset_n) SRAM wait state time for write accesses after the first read.

Table 204: Static Memory Write Delay 0–3 registers

Static Memory Turn Round Delay 0–3 registers

Address: A070 0218 / 0238 / 0258 / 0278

The Static Memory Turn Round Delay 0–3 registers allow you to program the number of bus turnaround cycles. It is recommended that these registers be modified during system initialization, or when there are no current or outstanding transactions. Wait until the memory controller is idle, then enter low-power or disabled mode.



Register bit assignment

Bits	Access	Mnemonic	Description
D31:04	N/A	Reserved	N/A (do not modify)
D03:00	R/W	WTTN	**Bus turnaround cycles (WAITTURN)** 0000–1110 (n + 1) HCLK turnaround cycles, where bus turnaround time is (WAITTURN + 1) x t_{HCLK} 1111 16 HCLK turnaround cycles (reset value on `reset_n`).

Table 205: Static Memory Turn Round Delay 0–3 registers

To prevent bus contention on the external memory databus, the WAITTURN field controls the number of bus turnaround cycles added between static memory read and write accesses.

The WAITTURN field also controls the number of turnaround cycles between static memory and dynamic memory accesses.

Ethernet Communication Module

CHAPTER 6

The Ethernet Communication module consists of an Ethernet Media Access Controller (MAC) and Ethernet front-end module. The Ethernet MAC interfaces to an external PHY through one of two industry-standard interfaces: MII and RMII. The Ethernet front-end module provides all of the control functions to the MAC.

Overview

The Ethernet MAC module provides the following:

- Station address logic (SAL)
- Statistics module
- Interface to MII (Media Independent Interface) PHY
- Interface to RMII (Reduced Media Independent Interface) PHY

The Ethernet front-end module does the following:

- Provides control functions to the MAC
- Buffers and filters the frames received from the MAC
- Pumps transmit data into the MAC
- Moves frames between the MAC and the system memory
- Reports transmit and receive status to the host

"Legend"

RX_RD = Receive read

RX_WR = Receive write

TX_RD = Transmit read

TX_WR = Transmit write

Figure 64 shows the Ethernet Communications module.

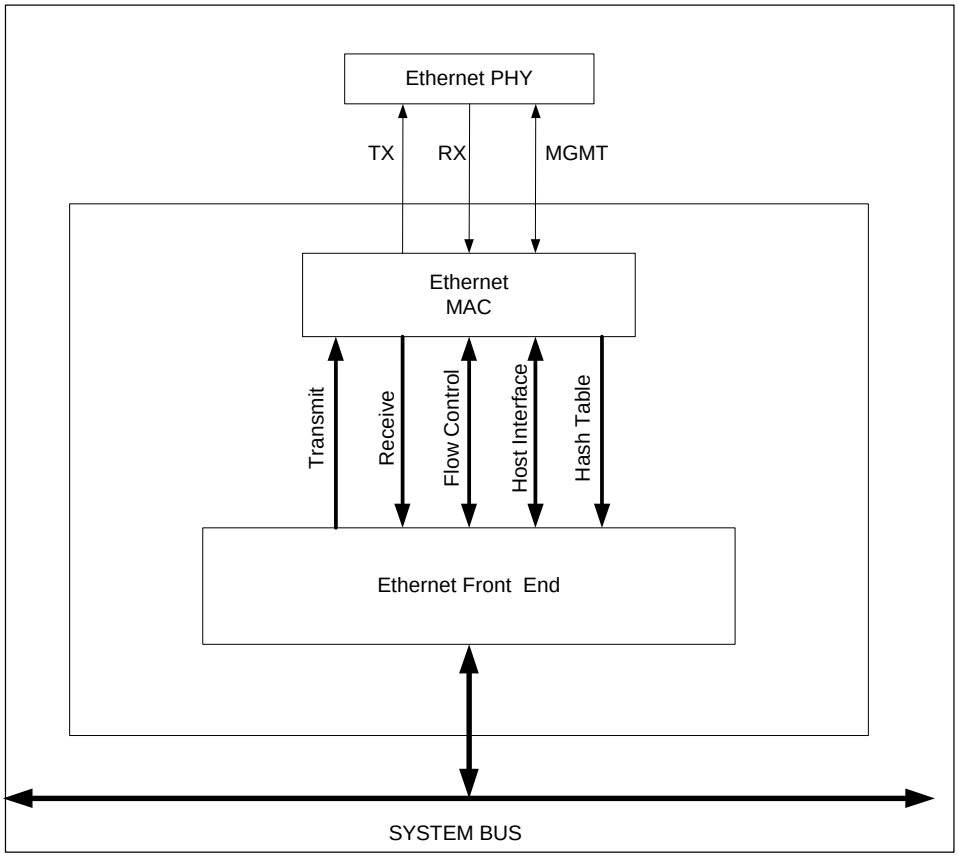


Figure 64: Ethernet Communication module block diagram

Ethernet MAC

The Ethernet MAC includes a full function 10/100 Mbps Media Access Controller (MAC), station address filtering logic (SAL), statistic collection module (STAT), and two software-selectable PHY interfaces — MII and RMII. Figure 65 shows the Ethernet MAC module block diagram, with its associated hierarchy. Table 207 describes the module's features.

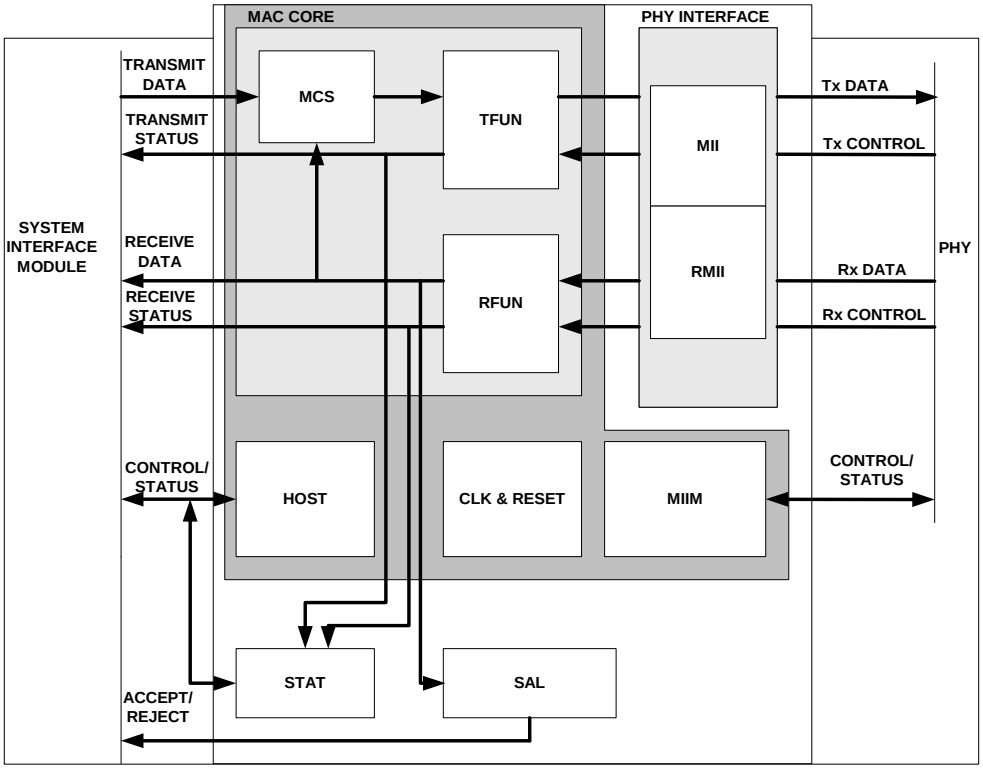


Figure 65: Ethernet MAC block diagram

Feature	Description
MAC Core	**10/100 megabit Media Access Controller** Performs the CSMA/CD function. ■ MCS: MAC control sublayer ■ TFUN: Transmit function ■ RFUN: Receive function
HOST	**Host interface** Provides an interface for control and configuration.
CLK & Reset	**Clocks & resets** Provides a central location for clock trees and reset logic.

Table 206: Ethernet MAC features

Feature	Description
MIIM	**MII management** Provides control/status path to MII and RMII PHYs.
STAT	**Statistics module** Counts and saves Ethernet statistics.
SAL	**Station address logic** Performs destination address filtering.
MII	**Media Independent Interface** Provides the interface from the MAC core to a PHY that supports the MII (as described in the IEEE 802.3 standard).
RMII	**Reduced Media Independent Interface** Provides the interface from the MAC core to a PHY that supports RMII. **Advisory:** Note that the NS9775 RMII interface incorrectly handles packets with dribble. (Dribble occurs when extra data is detected on the end of a packet, but there is insufficient data to form a new byte.) In some cases, packets with dribble will be passed through with the extra data truncated; this is the correct handling, and the packet is treated as a normal packet without error. In other cases, packets with dribble will be passed through with an extra byte at the end. In these situations, the packet is rejected correctly because it appears to have an invalid FCS. In addition, the dribble bit (RXDR) in the status field of RX Ethernet packets and in the Ethernet Receive Status register (see "Ethernet Receive Status register" on page 358) may be falsely set for packets that do not have any dribble bits. For RMII, the dribble bit should be ignored. For RMII, ignore the Receive Alignment Error Counter and the Receive FCS Error Counter. Set the M1RFC and M1RAL bits in the Carry Register 1 Mask register to 1 so no interrupts will be caused when these counters overflow.

Table 206: Ethernet MAC features

Table 207 shows how the different PHY interfaces are mapped to the external IO. In addition to these signals, NS9775 has a dedicated interrupt input for the external PHY (`enet_phy_int`).

External IO	MII	RMII
RXD[3]	RXD[3]	N/C Pull low external to NS9775
RXD[2]	RXD[2]	N/C Pull low external to NS9775
RXD[1]	RXD[1]	RXD[1]
RXD[0]	RXD[0]	RXD[0]
RX_DV	RX_DV	N/C Pull low external to NS9775
RX_ER	RX_ER	RX_ER Optional signal; pull low external to NS9775 if not being used
RX_CLK	RX_CLK	REF_CLK
TXD[3]	TXD[3]	N/C
TXD[2]	TXD[2]	N/C
TXD[1]	TXD[1]	TXD[1]
TXD[0]	TXD[0]	TXD[0]
TX_EN	TX_EN	TX_EN
TX_ER	TX_ER	N/C
TX_CLK	TX_CLK	N/C Pull low external to NS9775
CRS	CRS	CRS_DV
COL	COL	N/C Pull low external to NS9775
MDC	MDC	MDC

Table 207: PHY interface mappings to external IO

External IO	MII	RMII
MDIO	MDIO	MDIO

Table 207: PHY interface mappings to external IO

Station address logic (SAL)

The station address logic module examines the destination address field of incoming frames, and filters the frames before they are stored in the Ethernet front-end module. The filtering options, listed next, are programmed in the Station Address Filter register (see page 377).

- Accept frames to destination address programmed in the SA1, SA2, and SA3 registers (Station Address registers, beginning on page 375)
- Accept all frames
- Accept all multicast frames
- Accept all multicast frames using HT1 and HT2 registers (Hash Table registers, beginning on page 377)
- Accept all broadcast frames

The filtering conditions are independent of each other; for example, the Station Address Logic register can be configured to accept all broadcast frames, and frames to the programmed destination address.

The MAC receiver provides the station address logic with a 6-bit CRC value that is the upper 6 bits of a 32-bit CRC calculation performed on the 48-bit multicast destination address. This 6-bit value addresses the 64-bit multicast hash table created in the HT1 and HT2 registers (see "Register Hash Tables" on page 377). If the current receive frame is a multicast frame and the 6-bit CRC addresses a bit in the hash table that is set to 1, the receive frame is accepted; otherwise, the frame is rejected. See "Sample hash table code," beginning on page 409, for sample C code to calculate hash table entries.

Statistics module

The Statistics module counts and saves Ethernet statistics in several counters (see "Statistics registers" on page 379).

The Ethernet General Control Register #2 contains three statistics module configuration bits:

- **AUTOZ.** Enable statistics counter clear on read.
- **CLRCNT.** Clear statistics counters.
- **STEN.** Enable statistics counters.

If any of the counters roll over, an associated carry bit is set in the Carry 1 (CAR1) or Carry 2 (CAR2) registers (see "General Statistics registers," beginning on page 388). Any statistics counter overflow can cause the STOVFL bit in the Ethernet Interrupt Status register (see page 396) to be set if its associated mask bit is not set in Carry Mask Register 1 or Carry Mask Register 2 (see "General Statistics registers," beginning on page 388).

The counters support a *clear on read* capability that is enabled when AUTOZ is set to 1 in the Ethernet General Control Register #2.

Ethernet front-end module

Figure 66 shows the Ethernet front-end module (EFE).

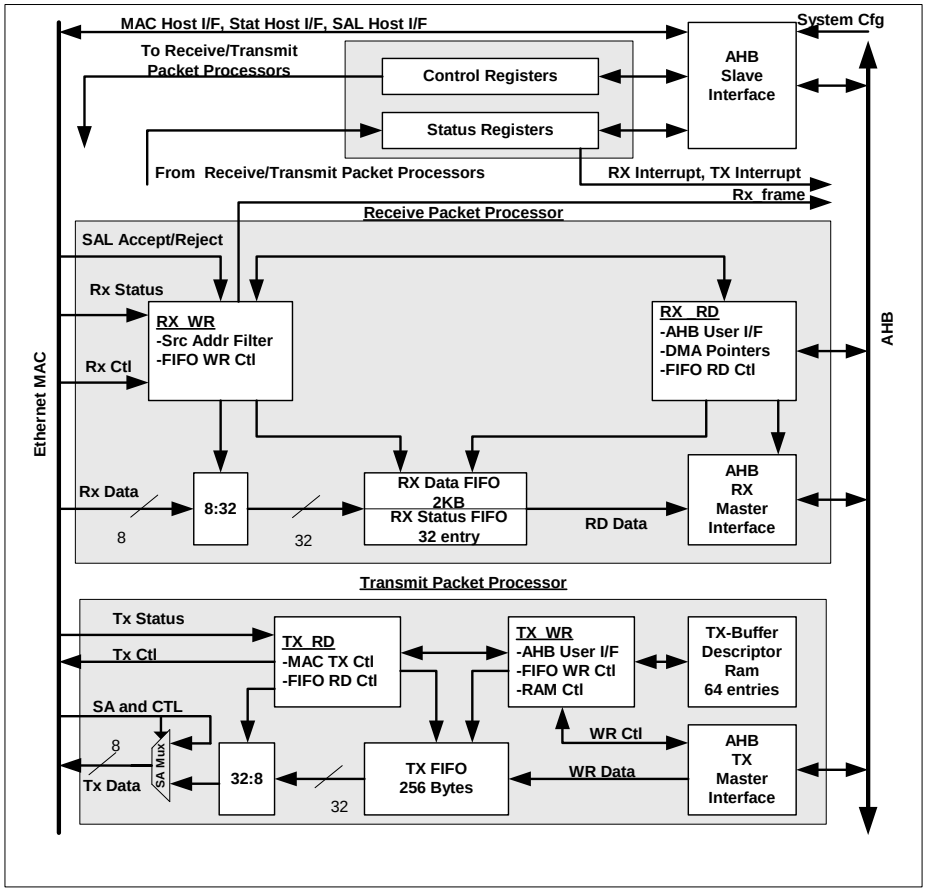


Figure 66: Ethernet front-end module block diagram

The EFE module includes a set of control and status registers, a receive packet processor, and a transmit packet processor. On one side, the Ethernet front end interfaces to the MAC and provides all control and status signals required by the MAC. On the other side, the Ethernet front end interfaces to the system.

The receive packet processor accepts good Ethernet frames (for example, valid checksum and size) from the Ethernet MAC and commits them to external system

memory. Bad frames (for example, invalid checksum or code violation) and frames with unacceptable destination addresses are discarded.

The 2K byte RX_FIFO allows the entire Ethernet frame to be buffered while the receive byte count is analyzed. The receive byte count is analyzed by the receive packet processor to select the optimum-sized buffer for transferring the received frame to system memory. The processor can use one of four different-sized receive buffers in system memory.

The transmit packet processor transfers frames constructed in system memory to the Ethernet MAC. The software initializes a buffer descriptor table in a local RAM that points the transmit packet processor to the various frame segments in system memory. The 256-byte TX_FIFO decouples the data transfer to the Ethernet MAC from the AHB bus fill rate.

Receive packet processor

As a frame is received from the Ethernet MAC, it is stored in the receive data FIFO. At the end of the frame, an accept/reject decision is made based on several conditions. If the packet is rejected, it is essentially flushed from the receive data FIFO.

If a frame is accepted, status signals from the MAC, including the receive size of the frame, are stored in a separate 32-entry receive status FIFO; the RX_RD logic is notified that a good frame is in the FIFO.

If the RX_WR logic tries to write a full receive data FIFO anytime during the frame, it flushes the frame from the receive data FIFO and sets RXOVFL_DATA (RX data FIFO overflowed) in the Ethernet Interrupt Status register. For proper operation, reset the receive packet processor using the ERX bit in the Ethernet General Control Register #1 when this condition occurs. If the RX_WR logic tries to write a full receive status FIFO at the end of the frame, the RX_WR logic flushes the frame from the receive data FIFO and sets RXOVFL_STAT (RX status FIFO overflowed) in the Ethernet Interrupt Status register.

Power down mode

The RX_WR logic supports the NS9775's system power down and recovery functionality. In this mode, the RX clock to the MAC and the RX_WR logic are still active, but the clock to the RX_RD and AHB interface is disabled. This allows frames to be received

and written into the receive FIFO, but the frame remains in the FIFO until the system wakes up. Normal frame filtering is still performed.

When a qualified frame is inserted into the receive FIFO, the receive packet processor notifies the system power controller, which performs the *wake up* sequence. The frame remains in the receive FIFO until the system wakes up.

Transferring a frame to system memory

The RX_RD logic manages the transfer of a frame in the RX_FIFO to system memory. The transfer is enabled by setting the ERXDMA (enable receive DMA) bit in Ethernet General Control Register #1.

Transferring a frame in the receive FIFO to system memory begins when the RX_WR logic notifies the RX_RD logic that a good frame is in the receive FIFO. Frames are transferred to system memory using up to four rings (that is, 1, 2, or 3 rings can also be used) of buffer descriptors that point to buffers in system memory. The maximum frame size that each ring can accept is programmable. The first thing the RX_RD logic does, then, is analyze the frame length in the receive status FIFO to determine which buffer descriptor to use.

The RX_RD logic goes through the four buffer descriptors looking for the optimum buffer size. It searches the enabled descriptors starting with A, then B, C, and finally D; any pools that are full (that is, the F bit is set in the buffer descriptor) are skipped. The search stops as soon as the logic encounters an available buffer that is large enough to hold the entire receive frame.

The pointers to the first buffer descriptor in each of the four pools are found in the related Buffer Descriptor Pointer register (RXAPTR, RXBPTR, RXCPTR, RXDPTR). Pointers to subsequent buffer descriptors are generated by adding an offset of 0x10 from this pointer for each additional buffer used.

Figure 67 shows the format of the buffer descriptors. The current buffer descriptor for each pool is kept in local registers. The current buffer descriptor registers are initialized to the buffer descriptors pointed to by the Buffer Descriptor Pointer registers, by setting the ERXINIT (enable initialization of RX buffer descriptor registers) bit in Ethernet General Control Register #1. The initialization process is complete when RXINIT (RX initialization complete) is set in the Ethernet General Status register. At the end of a frame, the next buffer descriptor for the ring just

used is read from system memory and stored in the registers internal to the RX_RD logic.

	31	30	29	28		16	15		0
OFFSET + 0	Source Address								
OFFSET + 4	Buffer Length (11 lower bits used)								
OFFSET + 8	Destination Address (not used)								
OFFSET + C	W	I	E	F	Reserved		Status		

Figure 67: Receive buffer descriptor format

Field	Description
W	WRAP bit, which, when set, tells the RX_RD logic that this is the last buffer descriptor in the ring. In this situation, the next buffer descriptor is found using the appropriate Buffer Descriptor Pointer register. When the WRAP bit is not set, the next buffer descriptor is found using an offset of 0x10 from the current buffer descriptor pointer.
I	When set, tells the RX_RD logic to set RXBUFC in the Ethernet Interrupt Status register (see page 396) after the frame has been transferred to system memory.
E	ENABLE bit, which, when set, tells the RX_RD logic that this buffer descriptor is enabled. When a new frame is received, pools that do not have the E bit set in their next buffer descriptor are skipped when deciding in which pool to put the frame. The receive processor can use up to four different-sized receive buffers in system memory.
Buffer pointer	32-bit pointer to the start of the buffer in system memory. This pointer must be aligned on a 32-bit boundary.
Status	Lower 16 bits of the Ethernet Receive Status register. The status is taken from the receive status FIFO and added to the buffer descriptor after the last word of the frame is written to system memory.
F	When set, indicates the buffer is full. The RX_RD logic sets this bit after filling a buffer. The system software clears this bit, as required, to free the buffer for future use. When a new frame is received, pools that have the F bit set in their next buffer descriptor are skipped when deciding in which pool to put the frame.

Field	Description
Buffer length	This is a dual use field: ■ When the buffer descriptor is read from system memory, buffer length indicates the maximum sized frame, in bytes, that can be stored in this buffer ring. ■ When the RX_RD logic writes the descriptor back from the receive status FIFO into system memory at the end of the frame, the buffer length is the actual frame length, in bytes.Only the lower 11 bits of this field are valid, since the maximum legal frame size for Ethernet is 1522 bytes.

Transmit packet processor

Transmit frames are transferred from system memory to the transmit packet processor into a 256-byte TX_FIFO. Because various parts of the transmit frame can reside in different buffers in system memory, several buffer descriptors can be used to transfer the frame.

All buffer descriptors (that is, up to 64) are found in a local TX buffer descriptor RAM. Figure 68 shows the transmit buffer descriptor format.

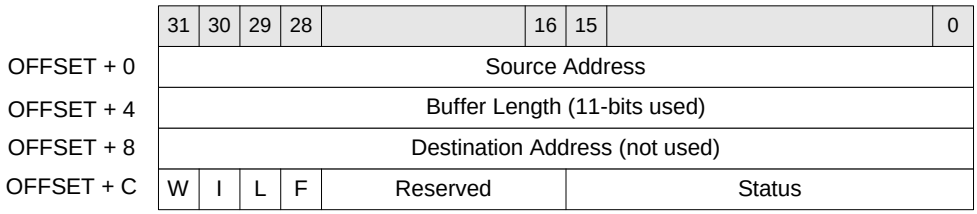


Figure 68: Transmit buffer descriptor format

Field	Description
W	WRAP bit, which, when set, tells the TX_WR logic that this is the last buffer descriptor within the continuous list of descriptors in the TX buffer descriptor RAM. The next buffer descriptor is found using the initial buffer descriptor pointer in the TX Buffer Descriptor Pointer register (TXPTR; see "TX Buffer Descriptor Pointer register," beginning on page 400). When the WRAP bit is not set, the next buffer descriptor is located at the next entry in the TX buffer descriptor RAM.

Field	Description
I	When set, tells the TX_WR logic to set TXBUFC in the Ethernet Interrupt Status register (see page 396) when the buffer is closed due to a normal channel completion.
Buffer pointer	32-bit pointer to the start of the buffer in system memory. This pointer can be aligned on any byte of a 32-bit word.
Status	Lower 16 bits of the Ethernet Transmit Status register. The status is returned from the Ethernet MAC at the end of the frame and written into the last buffer descriptor of the frame.
L	When set, tells the TX_WR logic that this buffer descriptor is the last descriptor that completes an entire frame. This bit allows multiple descriptors to be chained together to make up a frame.
F	When set, indicates the buffer is full. The TX_WR logic clears this bit after emptying a buffer. The system software sets this bit as required, to signal that the buffer is ready for transmission. If the TX_WR logic detects that this bit is not set when the buffer descriptor is read, it does one of two things: ■ If a frame is not in progress, the TX_WR logic sets the TXIDLE bit in the Ethernet Interrupt Status register. ■ If a frame is in progress, the TXBUFNR bit in the Ethernet Interrupt Status register is set. In either case, the TX_WR logic stops processing frames until TCLER (clear transmit logic) in Ethernet General Control Register #2 is toggled from low to high. TXBUFNR is set only for frames that consist of multiple buffer descriptors and contain a descriptor — *not* the first descriptor — that does not have the F bit set after frame transmission has begun.

Field	Description
Buffer length	This is a dual use field: ■ When the buffer descriptor is read from the TX buffer descriptor RAM, buffer length indicates the length of the buffer, in bytes. The TX_WR logic uses this information to identify the end of the buffer. For proper operation of the TX_WR logic, all transmit frames must be at least 34 bytes in length. ■ When the TX_WR logic updates the buffer descriptor at the end of the frame, it writes the length of the frame, in bytes, into this field for the last buffer descriptor of the frame. If the MAC is configured to add the CRC to the frame (that is, CRCEN in MAC Configuration Register #2 is set to 1), this field will include the four bytes of CRC. This field is set to 0x000 for jumbo frames that are aborted (see "TXAJ" on page 356) Only the lower 11 bits of this field are valid, since the maximum legal frame size for Ethernet is 1522 bytes.

Setting the EXTDMA (enable transmit DMA) bit in Ethernet General Control Register #1 starts the transfer of transmit frames from the system memory to the TX_FIFO. The TX_WR logic reads the first buffer descriptor in the TX buffer descriptor RAM.

- If the F bit is set, it transfers data from system memory to the TX_FIFO using the buffer pointer as the starting point. This process continues until the end of the buffer is reached. The address for each subsequent read of the buffer is incremented by 32 bytes (that is, 0x20). The buffer length field in the buffer descriptor is decremented by this same value, each transfer, to identify when the end of the buffer is reached.
- If the L field in the buffer descriptor is 0, the next buffer descriptor in the RAM continues the frame transfer until the L field in the current buffer descriptor is 1. This identifies the current buffer as the last buffer of a transmit frame.

After the entire frame has been written to the TX_FIFO, the TX_WR logic waits for a signal from the TX_RD logic indicating that frame transmission has completed at the MAC. The TX_WR logic updates the buffer length, status, and F fields of the current buffer descriptor (that is, the last buffer descriptor for the frame) in the TX buffer descriptor RAM when the signal is received.

The TX_WR logic examines the status received from the MAC after it has transmitted the frame.

- If the frame was transmitted successfully, the TX_WR logic sets TXDONE (frame transmission complete) in the Ethernet Interrupt Status register and reads the next buffer descriptor. If a new frame is available (that is, the F bit is set), the TX_WR starts transferring the frame. If a new frame is not available, the TX_WR logic sets the TXIDLE (TX_WR logic has no frame to transmit) bit in the Ethernet Interrupt Status register and waits for the software to toggle TCLER (clear transmit logic), in Ethernet General Control Register #2, from low to high to resume processing. The TX_WR logic also loads the 8-bit TX buffer descriptor RAM address of the buffer descriptor that did not have the F bit set in the TX Stall Buffer Descriptor Pointer register (see page 402). This allows identification of the buffer descriptor that caused this condition. As part of the recovery procedure, software must read the TX Stall Buffer Descriptor Pointer register and then write the 8-bit address of the buffer descriptor to resume transmission into the TX Recover Buffer Descriptor Pointer register.
- If the TX_WR logic detects that the frame was aborted or had an error, the logic updates the current buffer descriptor as described in the previous paragraph. If the frame was aborted before the last buffer descriptor of the frame was accessed, the result is a situation in which the status field of a buffer descriptor, which is not the last buffer descriptor in a frame, has a non-zero value. The TX_WR logic stops processing frames until TCLER (clear transmit logic) in Ethernet General Control Register #2 is toggled from low to high to resume processing. The TX_WR logic also sets TXERR (last frame not transmitted successfully) in the Ethernet Interrupt Status register and loads the TX buffer descriptor RAM address of the current buffer descriptor in the TX Error Buffer Descriptor Pointer register (see page 401). This allows identification of the frame that was not transmitted successfully. As part of the recovery procedure, software must read the TX Error Buffer Descriptor Pointer register and then write the 8-bit address of the buffer descriptor to resume transmission into the TX Recover Buffer Descriptor Pointer register.

Transmitting a frame to the Ethernet MAC

The TX_RD logic is responsible for reading data from the TX_FIFO and sending it to the Ethernet MAC. The logic does not begin reading a new frame until the TX_FIFO is full. This scheme decouples the data transfer to the Ethernet MAC from the fill rate from

the AHB bus. For short frames that are less than 256 bytes, the transmit process begins when the end-of-frame signal is received from the TX_WR logic.

When the MAC completes a frame transmission, it returns status bits that are stored in the Ethernet Transmit Status register (see page 354) and written into the status field of the current buffer descriptor.

Ethernet Slave Interface

The AHB slave interface supports only single 32-bit transfers. The slave interface also supports limiting CSR and RAM accesses to CPU “privileged mode” accesses. Use the internal register access mode bit 0 in the Miscellaneous System Configuration register to set access accordingly (see "Miscellaneous System Configuration and Status register," beginning on page 169).

The slave also generates an AHB ERROR if the address is not aligned on a 32-bit boundary, and the misaligned bus address response mode is set in the Miscellaneous System Configuration register (see "Miscellaneous System Configuration and Status register," beginning on page 169). In addition, accesses to non-existent addresses result in an AHB ERROR response.

Interrupts

Separate RX and TX interrupts are provided back to the system. Table 208 shows all interrupt sources and the interrupts to which they are assigned.

Interrupt condition	Description	Interrupt
RX data FIFO overflow	RX data FIFO overflowed. For proper operation, reset the receive packet processor using the ERX bit in the Ethernet General Control Register #1 when this condition occurs.	RX
RX status FIFO overflow	RX status overflowed.	RX
Receive buffer closed	I bit set in receive buffer descriptor and buffer closed.	RX
Receive complete (Pool A)	Complete receive frame stored in pool A of system memory.	RX

Table 208: Ethernet interrupt conditions

Interrupt condition	Description	Interrupt
Receive complete (Pool B)	Complete receive frame stored in pool B of system memory.	RX
Receive complete (Pool C)	Complete receive frame stored in pool C of system memory.	RX
Receive complete (Pool D)	Complete receive frame stored in pool D of system memory.	RX
No receive buffers	No buffer is available for this frame because all 4 buffer rings are disabled, full, or no available buffer is big enough for the frame.	RX
Receive buffers full	No buffer is available for this frame because all 4 buffers are disabled or full.	RX
RX buffer ready	Frame available in RX_FIFO. (Used for diagnostics.)	RX
Statistics counter overflow	One of the statistics counters has overflowed. Individual counters can be masked using the CAM1 and CAM2 registers.	TX
Transmit buffer closed	I bit set in Transmit buffer descriptor and buffer closed.	TX
Transmit buffer not ready	F bit not set in transmit buffer descriptor when read from TX buffer descriptor RAM, for a frame in progress.	TX
Transmit complete	Frame transmission complete.	TX
TXERR	Frame not transmitted successfully.	TX
TXIDLE	TX_WR logic in idle mode because there are no frames to send.	TX

Table 208: Ethernet interrupt conditions

The status bits for all interrupts are available in the Ethernet Interrupt Status register, and the associated enables are available in the Ethernet Interrupt Enable register. Each interrupt status bit is cleared by writing a 1 to it.

Resets

Table 209 provides a summary of all resets used for the Ethernet front-end and MAC, as well as the modules the resets control. See the *NS9775 Sample Driver Configurations* for examples of how the resets are used.

Bit field	Register	Active state	Default state	Modules reset
ERX	Ethernet General Control Register #1	0	0	RX_RD, RX_WR
ETX	Ethernet General Control Register #1	0	0	TX_RD, TX_WR
MAC_HRST	Ethernet General Control Register #1	1	0	MAC, STAT, RMII, RX_WR, TX_RD, programmable registers in Station Address Logic
SRST	MAC1	1	1	MAC (except programmable registers), Station Address Logic (except programmable registers), RMII, RX_WR, TX_RD
RPERFUN	MAC1	1	0	MAC RX logic
RPEMCST	MAC1	1	0	MAC PEMCS (TX side)
RPETFUN	MAC1	1	0	MAC TX logic
RMIIM	MII Management Configuration register	1	0	MAC MIIM logic
RPERMII	PHY Support register	1	0	RMII

Table 209: Reset control

External CAM filtering

NS9775 supports external Ethernet CAM filtering, which requires an external CAM controller to operate in conjunction with the MAC inside NS9775. The interface to the CAM controller is provided through GPIO in NS9775. External CAM filtering uses these bits:

- GPIO[19] configured as an output and for function 0
- GPIO[18] configured as an input and for function 0

For MII PHYs, the `CAM_REQ (GPIO[19])` signal is driven high by NS9775, to identify the beginning of each Ethernet frame being transferred to NS9775. The signal is driven

high coincident with the 6th nibble of the packet from the frame. The external CAM hardware must monitor the MII receive interface between the PHY and the MAC waiting for the CAM_REQ assertion. When CAM_REQ is asserted, the CAM hardware can extract the destination address field from the MII receive bus. As an alternative, the external CAM hardware can use the RX_DV signal from the MII PHY to detect the start of a frame.

After performing the necessary destination address lookup, the incoming frame can be rejected by CAM filtering hardware by asserting the CAM_REJECT (GPIO[20]) input high. This signal must be asserted no later than the 4th nibble from the end of the frame. Once it is asserted, it must remain asserted until three RX_CLKs after the end of the frame, to guarantee that the RX_WR logic has captured it. For example, a 64-byte frame contains 128 nibbles of data on the MII interface. CAM_REJECT must be valid by the 123rd nibble of data (first nibble is 0th nibble).

Figure 69 shows the timing relationship between the CAM_REQ, CAM_REJECT, and MII receive interface signals when using an MII PHY.

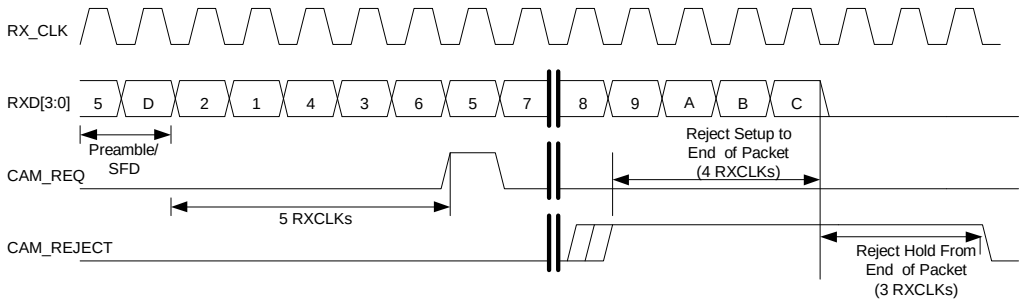


Figure 69: External Ethernet CAM filtering for MII PHY

In this example, the MII receive interface is transferring a frame whose first 6 nibbles have the values 1, 2, 3, 4, 5, and 6. The external CAM hardware uses the CAM_REQ signal to find the alignment for the destination address. After lookup is performed, the CAM hardware can assert the CAM_REJECT signal to discard the frame. The CAM_REJECT signal must be asserted no later than the 4th nibble from the end of the frame.

For RMII PHYs, the external CAM filtering logic is different, because the PHY interface is 2 bits at 50 MHz rather than the 4 bits at 25 MHz for a MII PHY. Because the CAM_REQ signal is generated from the 25 MHz clock, it cannot be used reliably with external 50 MHz logic to identify the start of a new frame. The external logic instead should use

the RMII PHY receive interface signals (that is, RXD[1:0], CRS_DV) to find the start of a frame, as shown in Figure 70. The RMII specification defines the start of a frame preamble when CRS_DV is high and RXD[1:0] transitions from 00 to 01. Per the specification, CRS_DV is asserted asynchronously to REF_CLK, to indicate the CRS function. When RXD[1:0] transitions from 00, however, CRS_DV performs the data valid function, and is negated and asserted synchronous to REF_CLK until the end of the frame.

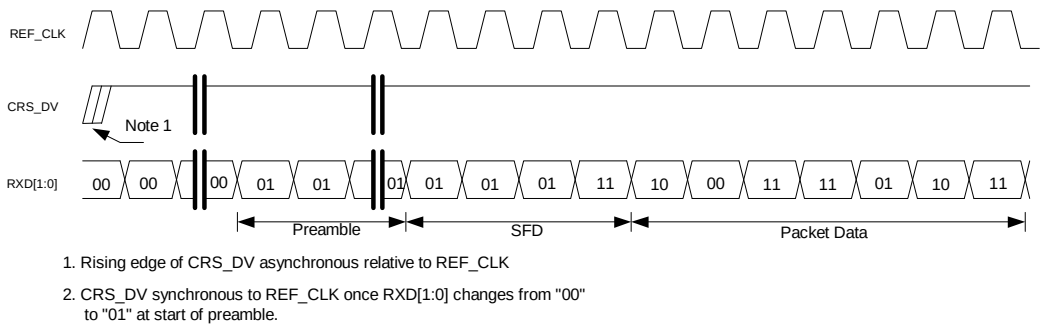


Figure 70: RMII PHY receive interface

After performing the necessary destination address lookup, the incoming frame can be rejected by the CAM filtering hardware by asserting the CAM_REJECT(GPIO[20]) input high, as shown in Figure 71. CAM_REJECT(GPIO[20]) must be asserted no later than one di-bit nibble before the end of the frame (that is, when CRS_DV is negated). Once the signal is asserted, it must remain asserted until 16 REF_CLKs (for 100 Mbps) or 128 REF_CLKS (for 10 Mbps) after the end of the frame, to guarantee that the RX_WR logic has captured it. For example, a 64-byte frame contains 256 di-bits (that is, 2 bits) of data on the RMII interface. CAM_REJECT must be valid by the 254th di-bit of data (the first di-bit is 0th di-bit).

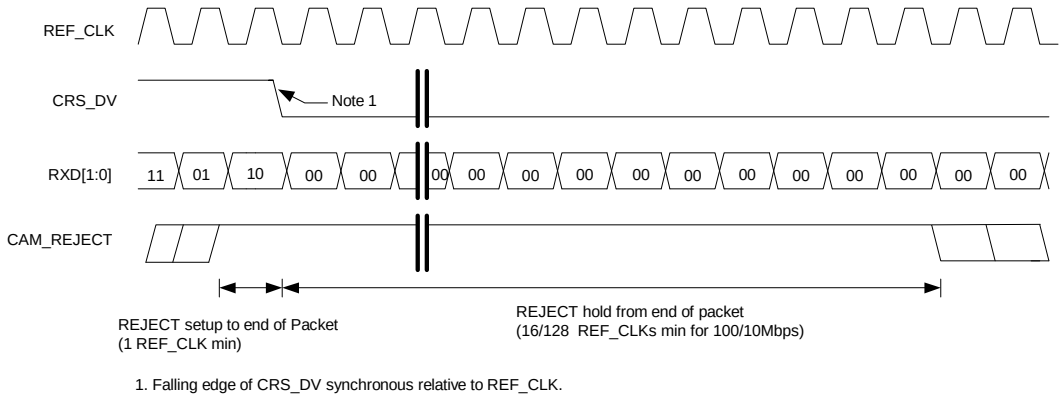


Figure 71: External Ethernet CAM filtering for RMII PHY

Ethernet Control and Status registers

Table 210 shows the address for each Ethernet controller register. All configuration registers must be accessed as 32-bit words and as single accesses only. No bursting is allowed.

Address	Register	Description
A060 0000	EGCR1	Ethernet General Control Register #1
A060 0004	EGCR2	Ethernet General Control Register #2
A060 0008	EGSR	Ethernet General Status register
A060 000C–A060 0014		Reserved
A060 0018	ETSR	Ethernet Transmit Status register
A060 001C	ERSR	Ethernet Receive Status register
A060 0400	MAC1	MAC Configuration Register #1
A060 0404	MAC2	MAC Configuration Register #2
A060 0408	IPGT	Back-to-Back Inter-Packet-Gap register
A060 040C	IPGR	Non-Back-to-Back Inter-Packet-Gap register

Table 210: Ethernet Control and Status register map

Address	Register	Description
A060 0410	CLRT	Collision Window/Retry register
A060 0414	MAXF	Maximum Frame register
A060 0418	SUPP	PHY Support register
A060 041C	Reserved	
A060 0420	MCFG	MII Management Configuration register
A060 0424	MCMD	MII Management Command register
A060 0428	MADR	MII Management Address register
A060 042C	MWTD	MII Management Write Data register
A060 0430	MRDD	MII Management Read Data register
A060 0434	MIND	MII Management Indicators register
A060 0440	SA1	Station Address Register #1
A060 0444	SA2	Station Address Register #2
A060 0448	SA3	Station Address register #3
A060 0500	SAFR	Station Address Filter register
A060 0504	HT1	Hash Table Register #1
A060 0508	HT2	Hash Table Register #2
A060 0680	STAT	Statistics Register Base (45 registers)
A060 0A00	RXAPTR	RX_A Buffer Descriptor Pointer register
A060 0A04	RXBPTR	RX_B Buffer Descriptor Pointer register
A060 0A08	RXCPTR	RX_C Buffer Descriptor Pointer register
A060 0A0C	RXDPTR	RX_D Buffer Descriptor Pointer register
A060 0A10	EINTR	Ethernet Interrupt Status register
A060 0A14	EINTREN	Ethernet Interrupt Enable register
A060 0A18	TXPTR	TX Buffer Descriptor Pointer register
A060 0A1C	TXRPTR	TX Recover Buffer Descriptor Pointer register
A060 0A20	TXERBD	TX Error Buffer Descriptor Pointer register
A060 0A24	TXSPTR	TX Stall Buffer Descriptor Pointer register

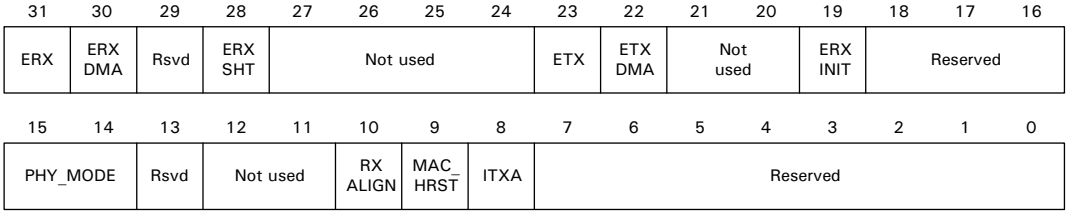
Table 210: Ethernet Control and Status register map

Address	Register	Description
A060 0A28	RXAOFF	RX_A Buffer Descriptor Pointer Offset register
A060 0A2C	RXBOFF	RX_B Buffer Descriptor Pointer Offset register
A060 0A30	RXCOFF	RX_C Buffer Descriptor Pointer Offset register
A060 0A34	RXDOFF	RX_D Buffer Descriptor Pointer Offset register
A060 0A38	TXOFF	Transmit Buffer Descriptor Pointer Offset register
A060 0A3C	RXFREE	RX Free Buffer register
A060 1000	TXBD	TX Buffer Descriptor RAM (256 locations)

Table 210: Ethernet Control and Status register map

Ethernet General Control Register #1

Address: A060 0000



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31	R/W	ERX	0	**Enable RX packet processing** (see "Receive packet processor" on page 334) 0 Reset RX 1 Enable RX Used as a soft reset for the RX. When cleared, resets all logic in the RX and flushes the FIFO. The ERX bit must be set active high to allow data to be received from the MAC receiver.

Table 211: Ethernet General Control Register #1

Bits	Access	Mnemonic	Reset	Description
D30	R/W	ERXDMA	0	**Enable receive DMA** 0 Disable receive DMA data request (use to stall receiver) 1 Enable receive DMA data request Must be set active high to allow the RX_RD logic to request the AHB bus to DMA receive frames into system memory. Set this bit to zero to temporarily stall the receive side Ethernet DMA. The RX_RD logic stalls on frame boundaries.
D29	N/A	Reserved	N/A	N/A
D28	R/W	ERXSHT	0	**Accept short (<64) receive frames** 0 Do not accept short frames 1 Accept short frames When set, allows frames that are smaller than 64 bytes to be accepted by the RX_WR logic. ERXSHT is typically set for debugging only.
D27:24	R/W	Not used	0	Always write as 0.
D23	R/W	ETX	0	**Enable TX packet processing** (see "Transmit packet processor" on page 337) 0 Reset TX 1 Enable TX Used as a soft reset for the TX. When cleared resets all logic in the TX and flushes the FIFOs. ETX must be set active high to allow data to be sent to the MAC and to allow processor access to the TX buffer descriptor RAM.

Table 211: Ethernet General Control Register #1

Bits	Access	Mnemonic	Reset	Description
D22	R/W	ETXDMA	0	**Enable transmit DMA** 0 Disable transmit DMA data request (use to stall transmitter) 1 Enable transmit DMA data request Must be set active high to allow the transmit packet processor to issue transmit data requests to the AHB interface. Set this bit to 0 to temporarily stall frame transmission, which always stalls at the completion of the current frame. The 8-bit address of the next buffer descriptor to be read in the TX buffer descriptor RAM is loaded into the TXSPTR register when the transmit process ends. If the transmit packet processor already is stalled and waiting for TCLER (see "TCLER" on page 353),clearing ETXDMA will not take effect until TCLER has been toggled. This bit generally should be set after the Ethernet transmit parameters (for example, buffer pointer descriptor) are programmed into the transmit packet processor.
D21	R/W	Not used	1	Always write as 1.
D20	R/W	Not used	0	Always write as 0.
D19	R/W	ERXINIT	0	**Enable initialization of RX buffer descriptors** 0 Do not initialize 1 Initialize When set, causes the RX_RD logic to initialize the internal buffer descriptor registers for each of the four pools from the buffer descriptors pointed to by RXAPTR, RXBPTR, RXCPTR, and RXDPTR. This is done as part of the RX initialization process. RXINIT is set in the Ethernet General Status register (see page 354) when the initialization process is complete, and ERXINIT must be cleared before enabling frame reception from the MAC. The delay from ERXINIT set to RXINIT set is less than five microseconds.
D18:16	N/A	Reserved	N/A	N/A

Table 211: Ethernet General Control Register #1

Bits	Access	Mnemonic	Reset	Description
D15:14	R/W	PHY_MODE	00	**Ethernet interface mode** 00 10/100 Mbit MII mode 01 10/100 Mbit RMII mode 10 Reserved 11 Reserved Identifies what type of Ethernet PHY is attached to NS9775. NS9775 supports two styles of Ethernet PHY: MII and RMII. This field should be changed only while the MAC is reset.
D13	N/A	Reserved	N/A	N/A
D12:11	R/W	Not used	0	Always write as 0.
D10	R/W	RXALIGN	0	**Align RX data** 0 Standard receive format. The data block immediately follows the 14-byte header block. 1 The receiver inserts a 2-byte padding between the 14-byte header and the data block, causing longword alignment for both the header and data blocks.
D09	R/W	MAC_HRST	1	**MAC host interface soft reset** 0 Restore MAC, STAT, SAL, RX_WR, and TX_RD to normal operation. 1 Reset MAC, STAT, programmable registers in SAL, RX_WR, and TX_RD. Keep high for minimum of 5μsec to guarantee that all functions get reset.

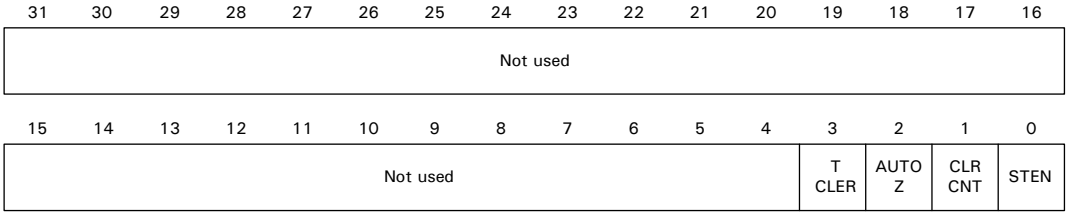
Table 211: Ethernet General Control Register #1

Bits	Access	Mnemonic	Reset	Description
D08	R/W	ITXA	0	**Insert transmit source address** 0 Source address for Ethernet transmit frame taken from data in TX_FIFO. 1 Insert the MAC Ethernet source address into the Ethernet transmit frame source address field. Set to force the MAC to automatically insert the Ethernet MAC source address into the Ethernet transmit frame source address. The SA1, SA2, and SA3 registers provide the address information. When the ITXA bit is cleared, the Ethernet MAC source address is taken from the data in the TX_FIFO.
D07:00	N/A	Reserved	N/A	N/A

Table 211: Ethernet General Control Register #1

Ethernet General Control Register #2

Address: A060 0004



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:04	R/W	Not used	0	Always write as 0.

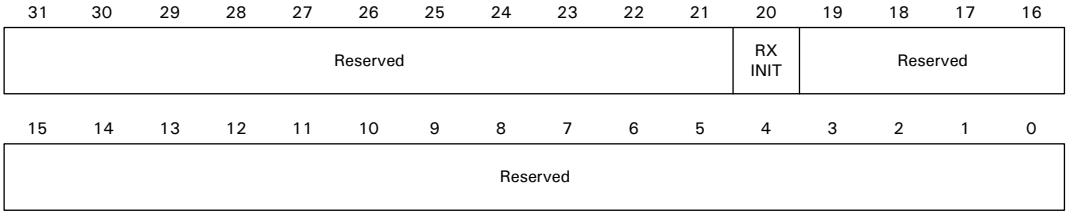
Table 212: Ethernet General Control Register #2

Bits	Access	Mnemonic	Reset	Description
D03	R/W	TCLER	0	**Clear transmit error** 0->1 transition: Clear transmit error. Clears out conditions in the transmit packet processor that have caused the processor to stop and require assistance from software before the processor can be restarted (for example, an AHB bus error or the TXBUFNR bit set in the Ethernet Interrupt Status register (see page 396)). Toggle this bit from low to high to restart the transmit packet processor.
D02	R/W	AUTOZ	0	**Enable statistics counter clear on read** 0 No change in counter value after read 1 Counter cleared after read When set, configures all counters in the Statistics module to clear on read. If AUTOZ is not set, the counters retain their value after a read. The counters can be cleared by writing all zeros.
D01	R/W	CLRCNT	1	**Clear statistics counters** 0 Do not clear all counters 1 Clear all counters When set, synchronously clears all counters in the Statistics module.
D00	R/W	STEN	0	**Enable statistics counters** 0 Counters disabled 1 Counters enabled When set, enables all counters in the Statistics module. If this bit is cleared, the counters will not update.

Table 212: Ethernet General Control Register #2

Ethernet General Status register

Address: A060 0008



Register bit assignment

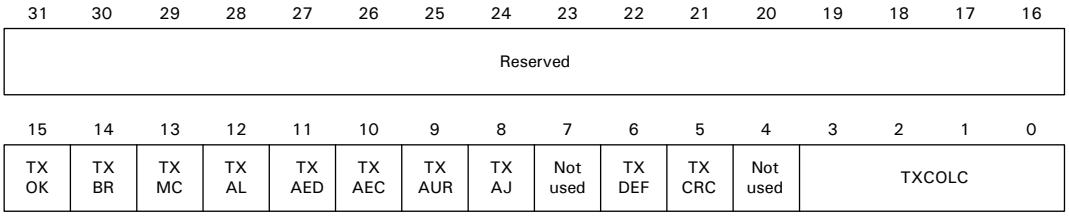
Bits	Access	Mnemonic	Reset	Description
D31:21	N/A	Reserved	N/A	N/A
D20	R/C	RXINIT	0x0	**RX initialization complete** Set when the RX_RD logic has completed the initialization of the local buffer descriptor registers requested when ERXINIT in Ethernet General Control Register #1 (see page 348) is set. The delay from ERXINIT set to RXINIT set is less than five microseconds.
D19:00	N/A	Reserved	N/A	N/A

Table 213: Ethernet General Status register

Ethernet Transmit Status register

Address: A060 0018

The Ethernet Status register contains the status for the last transmit frame. The TXDONE bit in the Ethernet Interrupt Status register (see page 396) is set upon completion of a transmit frame and the Ethernet Transmit Status register is loaded at the same time. Bits [15:0] are also loaded into the Status field of the last transmit buffer descriptor for the frame.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:16	N/A	Reserved	N/A	N/A
D15	R	TXOK	0x0	**Frame transmitted OK** When set, indicates that the frame has been delivered to and emptied from the transmit FIFO without problems.
D14	R	TXBR	0x0	**Broadcast frame transmitted** When set, indicates the frame's destination address was a broadcast address.
D13	R	TXMC	0x0	**Multicast frame transmitted** When set, indicates the frame's destination address was a multicast address.
D12	R	TXAL	0x0	**TX abort — late collision** When set, indicates that the frame was aborted due to a collision that occurred beyond the collision window set in the Collision Window/ Retry register (see page 377). If this bit is set, the TX_WR logic stops processing frames and sets the TXERR bit in the Ethernet Interrupt Status register.

Table 214: Ethernet Transmit Status register

Bits	Access	Mnemonic	Reset	Description
D11	R	TXAED	0x0	**TX abort — excessive deferral** When set, indicates that the frame was deferred in excess of 6071 nibble times in 100 Mbps or 24,287 times in 0 Mbps mode. This causes the frame to be aborted if the *excessive deferral bit* is set to 0 in MAC Configuration Register #2 (see page 361). If TXAED is set, the TX_WR logic stops processing frames and sets the TXERR bit in the Ethernet Interrupt Status register.
D10	R	TXAEC	0x0	**TX abort — excessive collisions** When set, indicates that the frame was aborted because the number of collisions exceeded the value set in the Collision Window/Retry register. If this bit is set, the TX_WR logic stops processing frames and sets the TXERR bit in the Ethernet Interrupt Status register.
D09	R	TXAUR	0x0	**TX abort — underrun** When set, indicates that the frame was aborted because the TX_FIFO had an underrun. If this bit is set, the TX_WR logic stops processing frames and sets the TXERR bit in the Ethernet Interrupt Status register.
D08	R	TXAJ	0x0	**TX abort — jumbo** When set, indicates that the frame's length exceeded the value set in the Maximum Frame register (see page 367). TXAJ is set only if the HUGE bit in MAC Configuration Register #2 (see page 361) is set to 0. Jumbo frames result in the TX buffer descriptor buffer length field (see "Buffer length" on page 337) being set to 0x000. If the HUGE bit is set to 0, the frame is truncated. If TXAJ is set, the TX_WR logic stops processing frames and sets the TXERR bit in the Ethernet Interrupt Status register.
D07	R	Not used	0x0	Always set to 0.

Table 214: Ethernet Transmit Status register

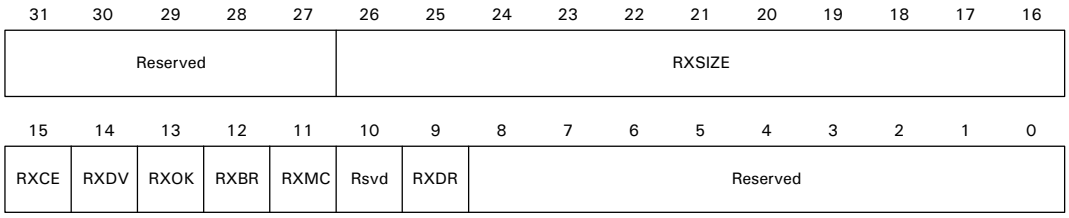
Bits	Access	Mnemonic	Reset	Description
D06	R	TXDEF	0x0	**Transmit frame deferred** When set, indicates that the frame was deferred for at least one attempt, but less than the maximum number for an excessive deferral. TXDEF is also set when a frame was deferred due to a collision. This bit is not set for late collisions.
D05	R	TXCRC	0x0	**Transmit CRC error** When set, indicates that the attached CRC in the frame did not match the internally-generated CRC. This bit is not set if the MAC is inserting the CRC in the frame (that is, the CRCEN bit is set in MAC Configuration Register #2). If TXCRC is set, the TX_WR logic stops processing frames and sets the TXERR bit in the Ethernet Interrupt Status register.
D04	R	Not used	0x0	Always set to 0.
D03:00	R	TXCOLC	0x0	**Transmit collision count** Number of collisions the frame incurred during transmission attempts.

Table 214: Ethernet Transmit Status register

Ethernet Receive Status register

Address: A060 001C

The Ethernet Receive Status register contains the status for the last completed receive frame. The RXBR bit in the Ethernet Interrupt Status register (see page 396) is set whenever a receive frame is completed and the Ethernet Receive Status register is loaded at the same time. Bits [15:0] are also loaded into the status field of the receive buffer descriptor used for the frame.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:27	N/A	Reserved	N/A	N/A
D26:16	R	RXSIZE	0x000	**Receive frame size in bytes** Length of the received frame, in bytes.

D15	R	RXCE	0x0	**Receive carrier event previously seen**
				When set, indicates that a *carrier event* activity (an activity on the receive channel that does not result in a frame receive attempt being made) was found at some point since the last receive statistics. A carrier event results when the interface signals to the PHY have the following values:
				`MRXER = 1`
				`MRXDV = 0`
				`RXD = 0xE`
				The event is being reported with this frame, although it is not associated with the frame.

Table 215: Ethernet Receive Status register

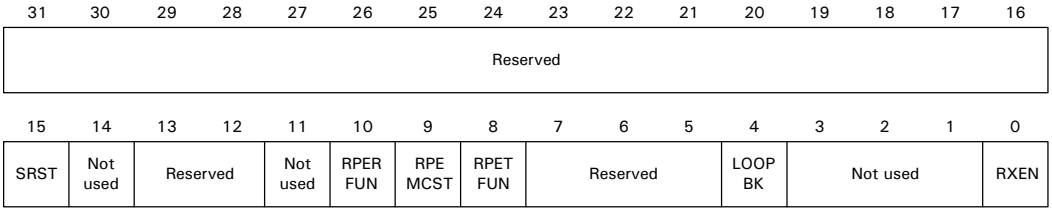
Bits	Access	Mnemonic	Reset	Description
D14	R	RXDV	0x0	**Receive data violation event previously seen** Set when the last receive event was not long enough to be a valid frame.
D13	R	RXOK	0x0	**Receive frame OK** Set when the frame had a valid CRC and no symbol errors.
D12	R	RXBR	0x0	**Receive broadcast frame** Set when the frame has a valid broadcast address.
D11	R	RXMC	0x0	**Receive multicast frame** Set when the frame has a valid multicast address.
D10	N/A	Reserved	N/A	N/A
D09	R	RXDR	0x0	**Receive frame has dribble bits** Set when an additional 1–7 bits are received after the end of the frame. **Note:** Ignore this bit with RMII applications.
D08:00	N/A	Reserved	N/A	N/A

Table 215: Ethernet Receive Status register

MAC Configuration Register #1

Address: A060 0400

MAC Configuration Register #1 provides bits that control functionality within the Ethernet MAC block.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:16	N/A	Reserved	N/A	N/A
D15	R/W	SRST	1	**Soft reset** Set this bit to 1 to reset the RX_WR, TX_RD, MAC (except host interface), SAL (except host interface), and RMII modules.
D14	R/W	Not used	0	Always write as 0.
D13:12	N/A	Reserved	N/A	N/A
D11	N/A	Not used	0	Always write as 0.
D10	R/W	RPERFUN	0	**Reset PERFUN** Set this bit to 1 to put the MAC receive logic into reset.
D09	R/W	RPEMCST	0	**Reset PEMCS/TX** Set this bit to 1 to put the MAC control sublayer/ transmit domain logic into reset.
D08	R/W	RPETFUN	0	**Reset PETFUN** Set this bit to 1 to put the MAC transmit logic into reset.
D07:05	N/A	Reserved	N/A	N/A

Table 216: MAC Configuration Register #1

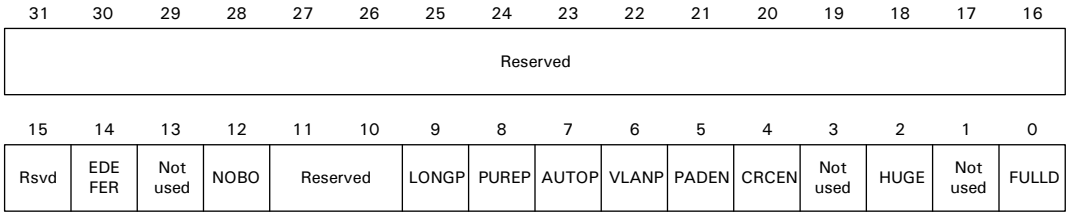
Bits	Access	Mnemonic	Reset	Description
D04	R/W	LOOPBK	0	**Internal loopback** Set this bit to 1 to cause the MAC transmit interface to be internally looped back to the MAC receive interface. Clearing this bit results in normal operation.
D03:01	R/W	Not used	0	Always write as 0.
D00	R/W	RXEN	0	**Receive enable** Set this bit to 1 to allow the MAC receiver to receive frames.

Table 216: MAC Configuration Register #1

MAC Configuration Register #2

Address: A060 0404

MAC Configuration Register #2 provides additional bits that control functionality within the Ethernet MAC block.



Register bit assignment

Bits	Access	Mnemonic	Reset	Definition
D31:15	N/A	Reserved	N/A	N/A

Table 217: MAC Configuration Register #2

Bits	Access	Mnemonic	Reset	Definition
D14	R/W	EDEFER	0	**Excess deferral** 0 The MAC aborts when the excessive deferral limit is reached (that is, 6071 nibble times in 100 Mbps mode or 24,287 bit times in 10 Mbps mode). 1 Enables the MAC to defer to carrier indefinitely, as per the 802.3u standard.
D13	R/W	Not used	0	Always write to 0.
D12	R/W	NOBO	0	**No backoff** When this bit is set to 1, the MAC immediately retransmits following a collision, rather than using the binary exponential backoff algorithm (as specified in the 802.3u standard).
D11:10	N/A	Reserved	N/A	N/A
D09	R/W	LONGP	0	**Long preamble enforcement** 0 Allows any length preamble (as defined in the 802.3u standard). 1 The MAC allows only receive frames that contain preamble fields less than 12 bytes in length.
D08	R/W	PUREP	0	**Pure preamble enforcement** 0 No preamble checking is performed 1 The MAC certifies the content of the preamble to ensure that it contains 0x55 and is error-free.
D07	R/W	AUTOP	0	**Auto detect pad enable** When set to 1, this bit causes the MAC to detect automatically the type of transmit frame, either tagged or untagged, by comparing the two octets following the source address with the 0x8100 VLAN protect ID and pad accordingly. **Note:** This bit is ignored if PADEN is set to 0. See "PAD operation table for transmit frames" on page 364 for more information.

Table 217: MAC Configuration Register #2

Bits	Access	Mnemonic	Reset	Definition
D06	R/W	VLANP	0	**VLAN pad enable** Set to 1 to have the MAC pad all short transmit frames to 64 bytes and to append a valid CRC. This bit is used in conjunction with auto detect pad enable (AUTOP) and pad/CRC enable (PADEN). See "PAD operation table for transmit frames" on page 364. **Note:** This bit is ignored if PADEN is set to 0.
D05	R/W	PADEN	0	**Pad/CRC enable** 0 Short transmit frames not padded. 1 The MAC pads all short transmit frames. This bit is used in conjunction with auto detect pad enable (AUTOP) and VLAN pad enable (VLANP). See "PAD operation table for transmit frames" on page 364.
D04	R/W	CRCEN	0	**CRC enable** 0 Transmit frames presented to the MAC contain a CRC. 1 Append a CRC to every transmit frame, whether padding is required or not. CRCEN must be set if PADEN is set to 1.
D03	R/W	Not used	0	Always write as 0.
D02	R/W	HUGE	0	**Huge frame enable** 0 Transmit and receive frames are limited to the MAXF value in the Maximum Frame register (see "Maximum Frame register" on page 367). 1 Frames of any length are transmitted and received.
D01	R/W	Not used	0	Always write as 0.
D00	R/W	FULLD	0	**Full-duplex** 0 The MAC operates in half-duplex mode. 1 The MAC operates in full-duplex mode.

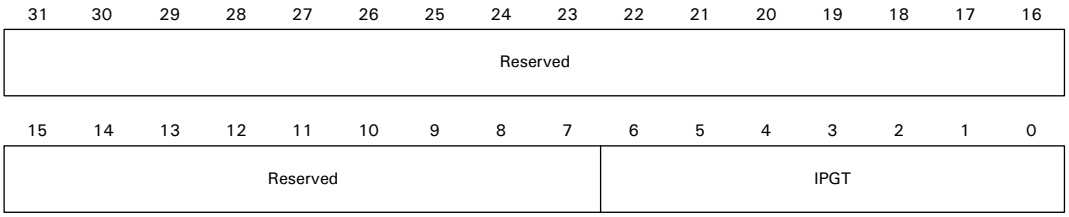
Table 217: MAC Configuration Register #2

PAD operation table for transmit frames

Type	AUTOP	VLANP	PADEN	Action
Any	X	X	0	No pad; check CRC
Any	0	0	1	Pad to 60 bytes; append CRC
Any	X	1	1	Pad to 64 bytes; append CRC
Any	1	0	1	If untagged, pad to 60 bytes; append CRC If VLAN tagged, pad to 64 bytes; append CRC

Back-to-Back Inter-Packet-Gap register

Address: A060 0408



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:07	N/A	Reserved	N/A	N/A

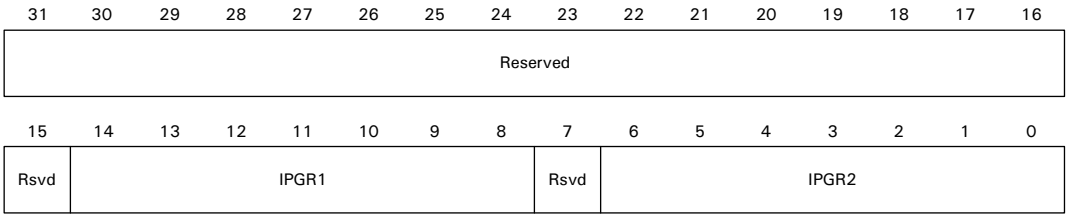
Table 218: Back-to-Back Inter-Packet-Gap register

Bits	Access	Mnemonic	Reset	Description
D06:00	R/W	IPGT	0x00	**Back-to-back inter-packet-gap** Programmable field that indicates the nibble time offset of the minimum period between the end of any transmitted frame to the beginning of the next frame. **Full-duplex mode** ■ Register value should be the appropriate period in nibble times minus 3. ■ Recommended setting is `0x15 (21d)`, which represents the minimum IPG of 0.96 uS (in 100 Mbps) or 9.6uS (in 10 Mbps). **Half-duplex mode** ■ Register value should be the appropriate period in nibble times minus 6. ■ Recommended setting is `0x12 (18d)`, which represents the minimum IPG of 0.96 uS (in 100 Mbps) or 9.6 uS (in 10 Mbps).

Table 218: Back-to-Back Inter-Packet-Gap register

Non Back-to-Back Inter-Packet-Gap register

Address: A060 040C



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:15	N/A	Reserved	N/A	N/A

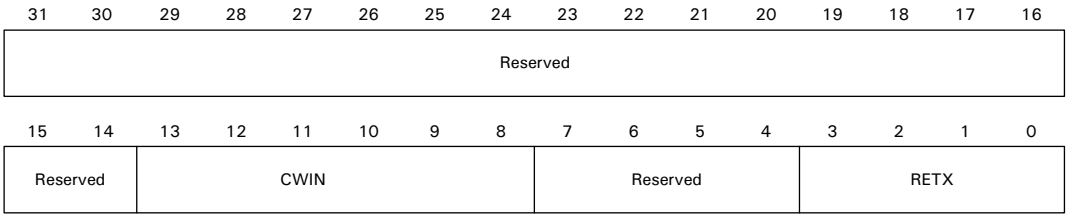
Table 219: Non Back-to-Back Inter-Packet-Gap register

Bits	Access	Mnemonic	Reset	Description
D14:08	R/W	IPGR1	0x00	**Non back-to-back inter-packet-gap part 1** Programmable field indicating optional carrierSense window (referenced in IEEE 8.2.3/ 4.2.3.2.1). ■ If carrier is detected during the timing of IPGR1, the MAC defers to carrier. ■ If carrier comes after IPGR1, the MAC continues timing IPGR2 and transmits — knowingly causing a collision. This ensures fair access to the medium. IPGR1's range of values is 0x0 to IPGR2. The recommended value is 0xC.
D07	N/A	Reserved	N/A	N/A
D06:00	R/W	IPGR2	0x00	**Non back-to-back inter-packet-gap part 2** Programmable field indicating the non back-to-back inter-packet-gap. The recommended value for this field is 0x12 (18d), which represents the minimum IPG of 0.96 µS in 100 Mbps or 9.6 µS in 10 Mbps.

Table 219: Non Back-to-Back Inter-Packet-Gap register

Collision Window/Retry register

Address: A060 0410



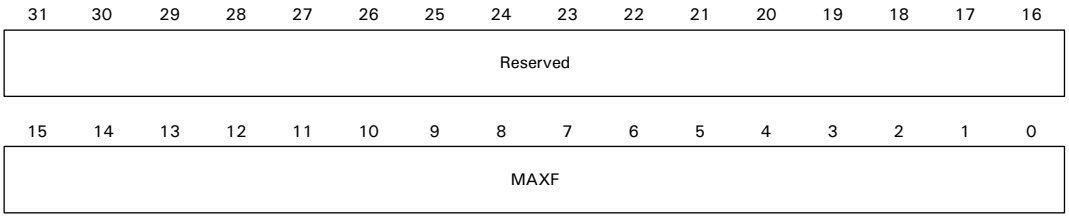
Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:14	N/A	Reserved	N/A	N/A
D13:08	R/W	CWIN	0x37	**Collision window** Programmable field indicating the slot time or collision window during which collisions occur in properly configured networks. Because the collision window starts at the beginning of transmissions, the preamble and SFD (start-of-frame delimiter) are included. The default value (0x37 (55d)) corresponds to the frame byte count at the end of the window.
D07:04	N/A	Reserved	N/A	N/A
D03:00	R/W	RETX	0xF	**Retransmission maximum** Programmable field specifying the number of retransmission attempts following a collision before aborting the frame due to excessive collisions. The 802.3u standard specifies the `attemptLimit` to be `0xF (15d)`.

Table 220: Collision Window/Retry register

Maximum Frame register

Address: A060 0414



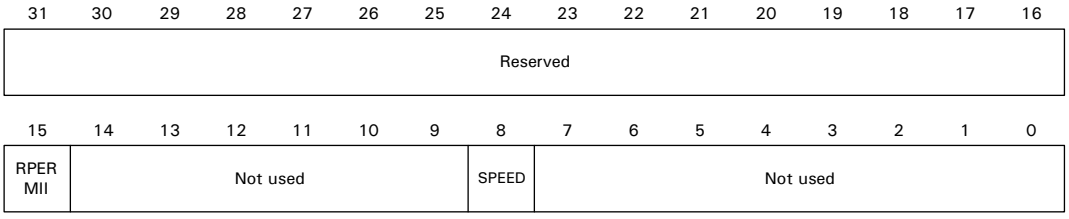
Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:16	N/A	Reserved	N/A	N/A
D15:00	R/W	MAXF	0x0600	**Maximum frame length** Default value of 0x600 represents a maximum receive frame of 1536 octets. An untagged maximum-size Ethernet frame is 1518 octets. A tagged frame adds four octets for a total of 1522 octets. To use a shorter maximum length restriction, program this field accordingly. **Note:** If a proprietary header is allowed, this field should be adjusted accordingly. For example, if 4-byte proprietary headers are prepended to the frames, the MAXF value should be set to 1526 octets. This allows the maximum VLAN tagged frame plus the 4-byte header.

Table 221: Maximum Frame register

PHY Support register

Address: A060 0418



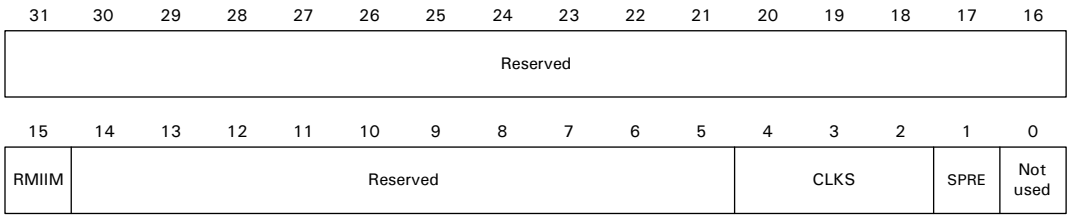
Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:16	N/A	Reserved	N/A	N/A
D15	R/W	RPERMII	0	**Reset RMII module** Set to 1 to reset the RMII PHY interface module logic.
D14:09	R/W	Not used	0x08	Always write 0x08.
D08	R/W	SPEED	0	**Speed select (RMII)** 0 RMII PHY interface logic is configured for 10 Mbps 1 RMII PHY interface logic is configured for 100 Mbps
D07:00	R/W	Not used	0x00	Always write 0x00.

Table 222: PHY Support register

MII Management Configuration register

Address: A060 0420



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:16	N/A	Reserved	N/A	N/A
D15	R/W	RMIIM	0	**Reset MII management block** Set this bit to 1 to reset the MII Management module.

Table 223: MII Management Configuration register

Bits	Access	Mnemonic	Reset	Description
D14:05	N/A	Reserved	N/A	N/A
D04:02	R/W	CLKS	0x0	**Clock select** Used by the clock divide logic in creating the MII management clock, which (per the IEEE 802.3u standard) can be no faster than 2.5 MHz. **Note:** Some PHYs support clock rates up to 12.5 MHz. The AHB bus clock is used as the input to the clock divide logic. "Clocks field settings," on page 370, shows the settings that are supported.
D01	R/W	SPRE	0	**Suppress preamble** 0 Causes normal cycles to be performed 1 Causes the MII Management module to perform read/write cycles without the 32-bit preamble field. (Preamble suppression is supported by some PHYs.)
D00	R/W	Not used	0	Always write to 0.

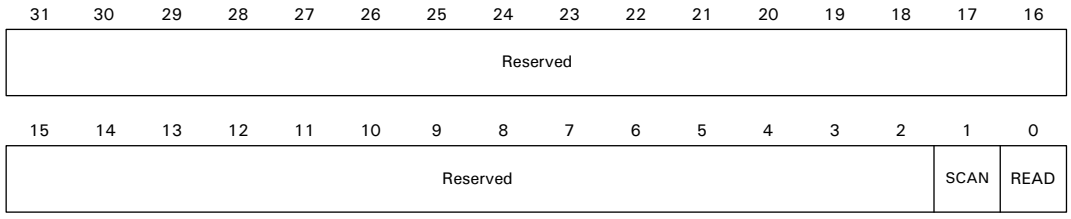
Table 223: MII Management Configuration register

Clocks field settings

CLKS field	Divisor	AHB bus clock for 2.5 MHz	AHB bus clock for 12.5 MHz
000	4		50 MHz
001	4		50 MHz
010	6		75 MHz
011	8		100 MHz
100	10		
101	20	50 MHz	
110	30	75 MHz	
111	40	100 MHz	

MII Management Command register

Address: A060 0424



Register bit assignment

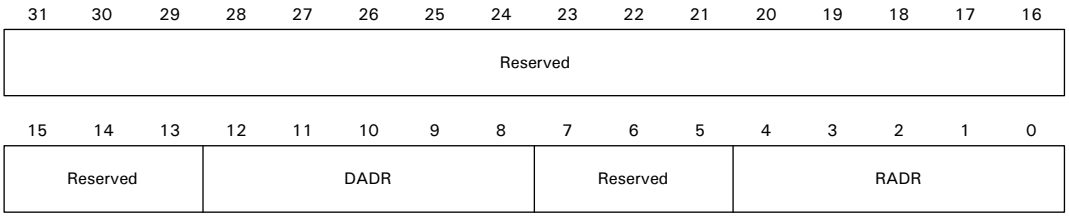
Note: If both SCAN and READ are set, SCAN takes precedence.

Bits	Access	Mnemonic	Reset	Description
D31:02	N/A	Reserved	N/A	N/A
D01	R/W	SCAN	0	**Automatically scan for read data** Set to 1 to have the MII Management module perform read cycles continuously. This is useful for monitoring link fail, for example.
D00	R/W	READ	0	**Single scan for read data** Set to 1 to have the MII Management module perform a single read cycle. The read data is returned in the MII Management Read Data register (see page 373) after the BUSY bit in the MII Management Indicators register (see page 374) has returned to a value of 0.

Table 224: MII Management Command register

MII Management Address register

Address: A060 0428



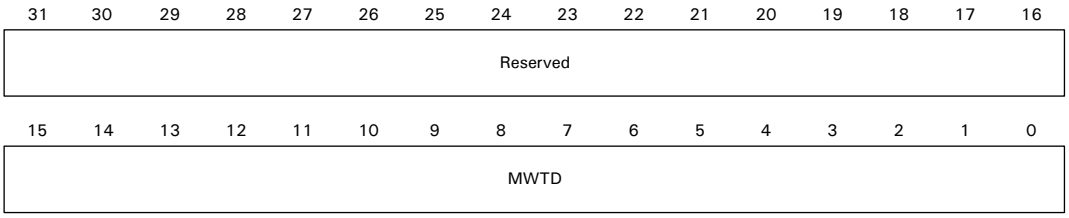
Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:13	N/A	Reserved	N/A	N/A
D12:08	R/W	DADR	0x00	**MII PHY device address** Represents the 5-bit PHY device address field for management cycles. Up to 32 different PHY devices can be addressed.
D07:05	N/A	Reserved	N/A	N/A
D04:00	R/W	RADR	0x00	**MII PHY register address** Represents the 5-bit PHY register address field for management cycles. Up to 32 registers within a single PHY device can be addressed.

Table 225: MII Management Address register

MII Management Write Data register

Address: A060 042C



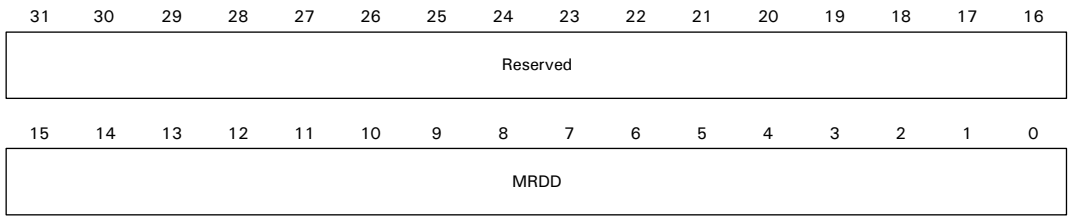
Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:16	N/A	Reserved	N/A	N/A
D15:00	R/W	MWTD	0x0000	**MII write data** When this register is written, an MII Management write cycle is performed using this 16-bit data along with the preconfigured PHY device and PHY register addresses defined in the MII Management Address register (see page 372). The write operation completes when the BUSY bit in the MII Management Indicators register (see page 374) returns to 0.

Table 226: MII Management Write Data register

MII Management Read Data register

Address: A060 0430



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:16	N/A	Reserved	N/A	N/A

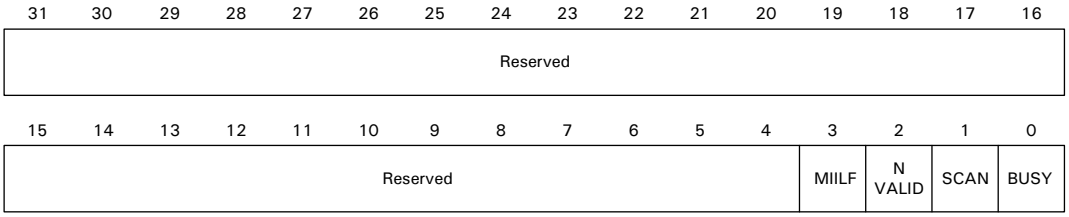
Table 227: MII Management Read Data register

Bits	Access	Mnemonic	Reset	Description
D15:00	R	MRDD	0x0000	**MII read data** Read data is obtained by reading from this register after an MII Management read cycle. An MII Management read cycle is executed by loading the MII Management Address register, then setting the READ bit to 1 in the MII Management Command register (see page 371). Read data is available after the BUSY bit in the MII Management Indicators register (see page 374) returns to 0.

Table 227: MII Management Read Data register

MII Management Indicators register

Address: A060 0434



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:04	N/A	Reserved	N/A	N/A
D03	R	MIILF	0	**MII link failure** When set to 1, indicates that the PHY currently has a link fail condition.

Table 228: MII Management Indicators register

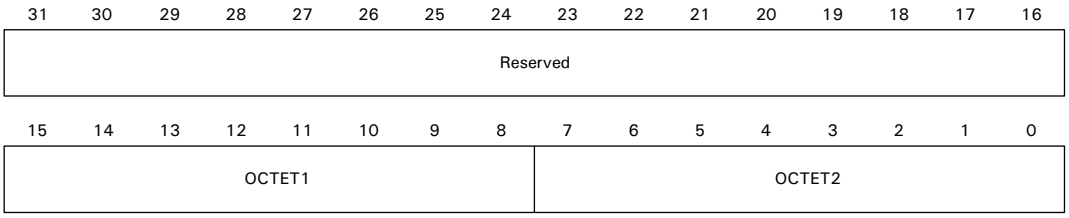
Bits	Access	Mnemonic	Reset	Description
D02	R	NVALID	0	**Read data not valid** When set to 1, indicates that the MII Management read cycle has not completed and the read data is not yet valid. Also indicates that SCAN READ is not valid for automatic scan reads.
D01	R	SCAN	0	**Automatically scan for read data in progress** When set to 1, indicates that continuous MII Management scanning read operations are in progress.
D00	R	BUSY	0	**MII interface BUSY with read/write operation** When set to 1, indicates that the MII Management module currently is performing an MII Management read or write cycle. This bit returns to 0 when the operation is complete.

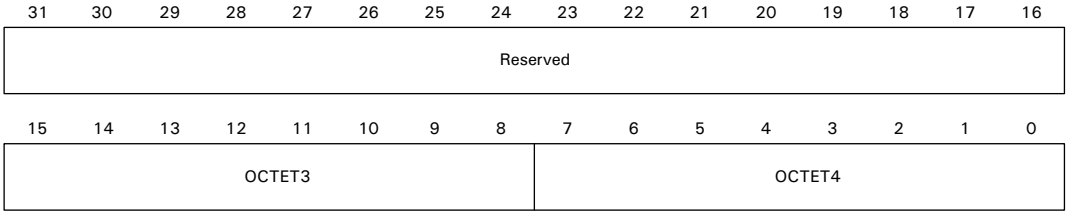
Table 228: MII Management Indicators register

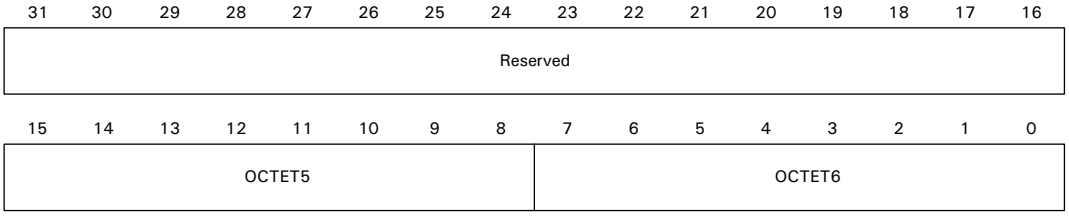
Station Address registers

Address: A060 0440 / 0444 / 0448

The 48-bit station address is loaded into Station Address Register #1, Station Address Register #2, and Station Address Register #3, for use by the station address logic (see "Station address logic (SAL)" on page 331).







Bits	Access	Mnemonic	Reset	Description
Station Address Register #1				
D31:16	N/A	Reserved	N/A	N/A
D15:08	R/W	OCTET1	0	Station address octet #1 (stad[7:0])
D07:00	R/W	OCTET2	0	Station address octet #2 (stad[15:8])
Station Address Register #2				
D31:16	N/A	Reserved	N/A	N/A
D15:08	R/W	OCTET3	0	Station address octet #3 (stad[23:16])
D07:00	R/W	OCTET4	0	Station address octet #4 (stad[31:24])
Station Address Register #3				
D31:16	N/A	Reserved	N/A	N/A
D15:08	R/W	OCTET5	0	Station address octet #5 (stad[39:32])
D07:00	R/W	OCTET6	0	Station address octet #6 (stad[47:40])

Table 229: Station Address registers

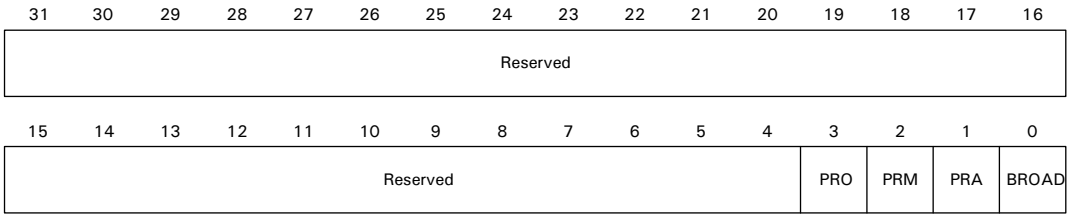
Note: Octet #6 is the first byte of a frame received from the MAC. Octet #1 is the last byte of the station address received from the MAC.

Station Address Filter register

Address: A060 0500

The Station Address Filter register contains several filter controls. The register is located in the station address logic (see "Station address logic (SAL)" on page 331).

All filtering conditions are independent of each other. For example, the station address logic can be programmed to accept all multicast frames, all broadcast frames, and frames to the programmed destination address.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:04	N/A	Reserved	N/A	N/A
D03	R/W	PRO	0	Enable promiscuous mode; receive all frames
D02	R/W	PRM	0	Accept all multicast frames
D01	R/W	PRA	0	Accept multicast frames using the hash table
D00	R/W	BROAD	0	Accept all broadcast frames

Table 230: Station Address Filter register

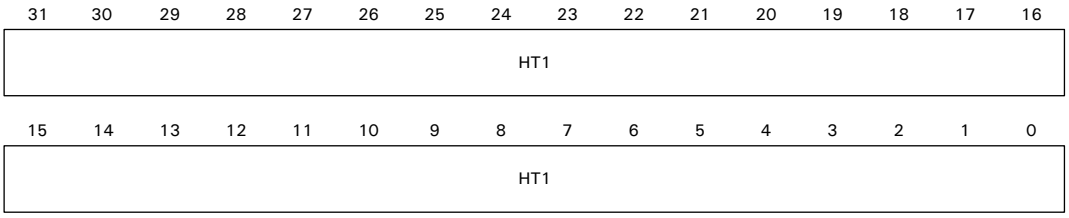
Register Hash Tables

The MAC receiver provides the station address logic with a 6-bit CRC value that is the upper six bits of a 32-bit CRC calculation performed on the 48-bit multicast destination address. This 6-bit value addresses the 64-bit multicast hash table created in HT1 (hash table 1) and HT2 (hash table 2). If the current receive frame is a multicast frame and the 6-bit CRC addresses a bit in the hash table that is set to 1, the receive frame will be accepted; otherwise, the receive frame is rejected.

HT1 stores enables for the lower 32 CRC addresses; HT2 stores enables for the upper 32 CRC addresses.

HT1

Address: A060 0504



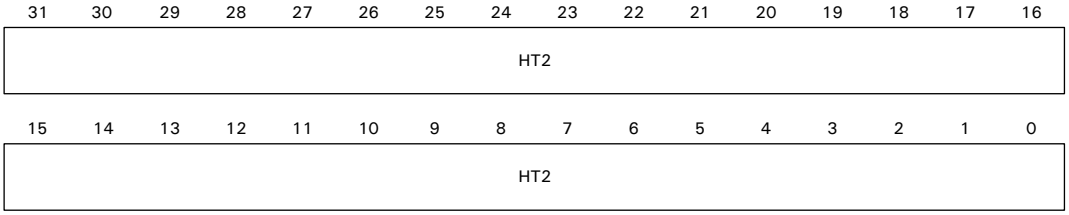
Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:00	R/W	HT1	0x00000000	CRC 31:00

Table 231: Hash Table Register 1

HT2

Address: A060 0508



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:00	R/W	HT2	0x00000000	CRC 63:32

Table 232: Hash Table Register 2

Statistics registers

Address: A060 0680 (base register)

The Statistics module has 39 counters and 4 support registers that count and save Ethernet statistics. The Ethernet General Control Register #2 contains three Statistics module configuration bits: AUTOZ, CLRCNT, and STEN. The counters support a "clear on read" capability that is enabled when AUTOZ is set to 1.

Combined transmit and receive statistics counters

The combined transmit and receive statistics counters, listed in Table 233, are incremented for each good or bad frame, transmitted and received, that falls within the specified frame length limits of the counter (for example, TR127 counts 65–127 byte frames). The frame length excludes framing bits and includes the FCS (checksum) bytes. All counters are 18 bits, with this bit configuration:

D31:18	R		Reserved
D17:00	R/W	Reset = 0x00000	Count (R/W)

Address	Register	Transmit and receive counters	R/W
A060_0680	TR64	Transmit & receive 64 Byte frame counter	R/W
A060_0684	TR127	Transmit & receive 65 to 127 Byte frame counter	R/W
A060_0688	TR255	Transmit & receive 128 to 255 Byte frame counter	R/W
A060_068C	TR511	Transmit & receive 256 to 511 Byte frame counter	R/W
A060_0690	TR1K	Transmit & receive 512 to 1023 Byte frame counter	R/W
A060_0694	TRMAX	Transmit & receive 1024 to 1518 Byte frame counter	R/W
A060_0698	TRMGV	Transmit & receive 1519 to 1522 Byte good VLAN frame count	R/W

Table 233: Combined transmit and receive statistics counters address map

Receive statistics counters

Address	Register	Receive counters	R/W
A060_069C	RBYT	Receive byte counter	R/W
A060_06A0	RPKT	Receive packet counter	R/W
A060_06A4	RFCS	Receive FCS error counter	R/W
A060_06A8	RMCA	Receive multicast packet counter	R/W
A060_06AC	RBCA	Receive broadcast packet counter	R/W
A060_06B0	RXCF	Receive control frame packet counter	R/W
A060_06B4	RXPF	Receive PAUSE frame packet counter	R/W
A060_06B8	RXUO	Receive unknown OPCODE counter	R/W
A060_06BC	RALN	Receive alignment error counter	R/W
A060_06C0	Reserved	N/A	N/A
A060_06C4	RCDE	Receive code error counter	R/W
A060_06C8	RCSE	Receive carrier sense error counter	R/W
A060_06CC	RUND	Receive undersize packet counter	R/W
A060_06D0	ROVR	Receive oversize packet counter	R/W
A060_06D4	RFRG	Receive fragments counter	R/W
A060_06D8	RJBR	Receive jabber counter	R/W
A060-06DC	Reserved	N/A	N/A

Table 234: Receive statistics counters address map

Receive byte counter (A060 069C)

Incremented by the byte count of frames received with 0 to 1518 bytes, including those in bad packets, excluding framing bits but including FCS bytes.

D31:24	R	Reset = Read as 0	Reserved
D23:00	R/W	Reset = 0x000000	RBYT

Receive packet counter (A060 06A0)
Incremented for each received frame (including bad packets, and all unicast, broadcast, and multicast packets).

D31:18	R	Reset = Read as 0	Reserved
D17:00	R/W	Reset = 0x00000	RPKT

Receive FCS error counter (A060 06A4)
Incremented for each frame received with a length of 64 to 1518 bytes, and containing a frame check sequence (FCS) error. FCS errors are not counted for VLAN frames that exceed 1518 bytes or for any frames with dribble bits.

D31:12	R	Reset = Read as 0	Reserved
D11:00	R/W	Reset = 0x000	RFCS

Ignore this counter for RMII applications as it does not operate properly.

Receive multicast packet counter (A060 06A8)
Incremented for each good multicast frame with a length no greater than 1518 bytes (non-VLAN) or 1522 bytes (VLAN), excluding broadcast frames. This counter does not look at range/length errors.

D31:18	R	Reset = Read as 0	Reserved
D17:00	R/W	Reset = 0x00000	RMCA

Receive broadcast packet counter (A060 06AC)
Incremented for each good broadcast frame with a length no greater than 1518 bytes (non-VLAN) or 1522 bytes (VLAN), excluding multicast frames. This counter does not look at range/length errors.

D31:18	R	Reset = Read as 0	Reserved
D17:00	R/W	Reset = 0x00000	RBCA

Receive control frame packet counter (A060 06B0)
Incremented for each MAC control frame received (PAUSE and unsupported).

D31:12	R	Reset = Read as 0	Reserved
D11:00	R/W	Reset = 0x000	RXCF

Receive PAUSE frame packet counter (A060 06B4)
Incremented each time a valid PAUSE control frame is received.

D31:12	R	Reset = Read as 0	Reserved
D11:00	R/W	Reset = 0x000	RXPF

Receive unknown OPCODE packet counter (A060 06B8)
Incremented each time a MAC control frame is received with an OPCODE other than PAUSE.

D31:12	R	Reset = Read as 0	Reserved
D11:00	R/W	Reset = 0x000	RBUO

Receive alignment error counter (A060 06BC)
Incremented for each received frame, from 64 to 1518 bytes, that contains an invalid FCS and has dribble bits (that is, is not an integral number of bytes).

D31:12	R	Reset = Read as 0	Reserved
D11:00	R/W	Reset = 0x000	RALN

Ignore this counter for RMII applications as it does not operate properly.

Receive code error counter (A060 06C4)
Incremented each time a valid carrier was present and at least one invalid data symbol was found.

D31:12	R	Reset = Read as 0	Reserved
D11:00	R/W	Reset = 0x000	RCDE

Receive carrier sense error counter (A060 06C8)
Incremented each time a false carrier is found during idle, as defined by a 1 on RX_ER and an 0xE on RXD. The event is reported with the statistics generated on the next received frame. Only one false carrier condition can be detected and logged between frames.

D31:12	R	Reset = Read as 0	Reserved
D11:00	R/W	Reset = 0x000	RCSE

Receive undersize packet counter (A060 06CC)
Incremented each time a frame is received that is less than 64 bytes in length, contains a valid FCS, and is otherwise well-formed. This counter does not look at range/length errors.

D31:12	R	Reset = Read as 0	Reserved
D11:00	R/W	Reset = 0x000	RUND

Receive oversize packet counter (A060 06D0)
Incremented each time a frame is received that exceeds 1518 bytes (non-VLAN) or 1522 bytes (VLAN), contains a valid FCS, and is otherwise well-formed. This counter does not look at range/length errors. This counter is not incremented when a packet is truncated because it exceeds the MAXF value.

D31:12	R	Reset = Read as 0	Reserved
D11:00	R/W	Reset = 0x000	ROVR

Receive fragments counter (A060 06D4)
Incremented for each frame received that is less than 64 bytes in length and contains an invalid FCS; this includes integral and non-integral lengths.

D31:12	R		Reserved
D11:00	R/W	Reset = 0x000	RFRG

Receive jabber counter (A060 06D8)
Incremented for frames received that exceed 1518 bytes (non-VLAN) or 1522 bytes (VLAN) and contain an invalid FCS, including alignment errors. This counter does not

increment when a packet is truncated to 1518 (non-VLAN) or 1522 (VLAN) bytes by MAXF.

D31:12	R	Reset = Read as 0	Reserved
D11:00	R/W	Reset = 0x000	RJBR

Transmit statistics counters

Address	Register	Transmit counters	R/W
A060_06E0	TBYT	Transmit byte counter	R/W
A060_06E4	TPKT	Transmit packet counter	R/W
A060_06E8	TMCA	Transmit multicast packet counter	R/W
A060_06EC	TBCA	Transmit broadcast packet counter	R/W
A060_06F0	Reserved	N/A	N/A
A060_06F4	TDFR	Transmit deferral packet counter	R/W
A060_06F8	TEDF	Transmit excessive deferral packet counter	R/W
A060_06FC	TSCL	Transmit single collision packet counter	R/W
A060_0700	TMCL	Transmit multiple collision packet counter	R/W
A060_0704	TLCL	Transmit late collision packet counter	R/W
A060_0708	TXCL	Transmit excessive collision packet counter	R/W
A060_070C	TNCL	Transmit total collision counter	R/W
A060_0710	Reserved	N/A	N/A
A060_0714	Reserved	N/A	N/A
A060_0718	TJBR	Transmit jabber frame counter	R/W
A060_071C	TFCS	Transmit FCS error counter	R/W
A060_0720	Reserved	N/A	N/A
A060_0724	TOVR	Transmit oversize frame counter	R/W
A060_0728	TUND	Transmit undersize frame counter	R/W
A060_072C	TFRG	Transmit fragments frame counter	R/W

Table 235: Transmit statistics counters address map

Transmit byte counter (A060 06E0)
Incremented by the number of bytes that were put on the wire, including fragments of frames that were involved with collisions. This count does not include preamble/SFD or jam bytes.

D31:24	R	Reset = Read as 0	Reserved
D23:00	R/W	Reset = 0x000000	TBYT

Transmit packet counter (A060 06E4)
Incremented for each transmitted packet (including bad packets, excessive deferred packets, excessive collision packets, late collision packets, and all unicast, broadcast, and multicast packets).

D31:18	R	Reset = Read as 0	Reserved
D17:00	R/W	Reset = 0x00000	TPKT

Transmit multicast packet counter (A060 06E8)
Incremented for each multicast valid frame transmitted (excluding broadcast frames).

D31:18	R	Reset = Read as 0	Reserved
D17:00	R/W	Reset = 0x00000	TMCA

Transmit broadcast packet counter (A060 06EC)
Incremented for each broadcast frame transmitted (excluding multicast frames).

D31:18	R	Reset = Read as 0	Reserved
D17:00	R/W	Reset = 0x00000	TBCA

Transmit deferral packet counter (A060 06F4)
Incremented for each frame that was deferred on its first transmission attempt. This counter does not include frames involved in collisions.

D31:12	R	Reset = Read as 0	Reserved
D11:00	R/W	Reset = 0x000	TDFR

Transmit excessive deferral packet counter (A060 06F8)
Incremented for frames aborted because they were deferred for an excessive period of time (3036 byte times).

D31:12	R	Reset = Read as 0	Reserved
D11:00	R/W	Reset = 0x000	TEDF

Transmit single collision packet counter (A060 06FC)
Incremented for each frame transmitted that experienced exactly one collision during transmission.

D31:12	R	Reset = Read as 0	Reserved
D11:00	R/W	Reset = 0x000	TSCL

Transmit multiple collision packet counter (A060 0700)
Incremented for each frame transmitted that experienced 2–15 collisions (including any late collisions) during transmission.

D31:12	R	Reset = Read as 0	Reserved
D11:00	R/W	Reset = 0x000	TMCL

Transmit late collision packet counter (A060 0704)
Incremented for each frame transmitted that experienced a late collision during a transmission attempt. Late collisions are defined using the CWIN[13:08] field of the Collision Window/Retry register.

D31:12	R	Reset = Read as 0	Reserved
D11:00	R/W	Reset = 0x000	TLCL

Transmit excessive collision packet counter (A060 0708)
Incremented for each frame transmitted that experienced excessive collisions during transmission, as defined by the RETX [03:00] field of the Collision Window/Retry register, and was aborted.

D31:12	R	Reset = Read as 0	Reserved
D11:00	R/W	Reset = 0x000	TXCL

Transmit total collision packet counter (A060 070C)
Incremented by the number of collisions experienced during the transmission of a frame.

Note: This register does not include collisions that result in an excessive collision count or late collisions.

D31:12	R	Reset = Read as 0	Reserved
D11:00	R/W	Reset = 0x000	TNCL

Transmit jabber frame counter (A060 0718)
Incremented for each oversized transmitted frame with an incorrect FCS value.

D31:12	R	Reset = Read as 0	Reserved
D11:00	R/W	Reset = 0x000	TJBR

Transmit FCS error counter (A060 071C)
Incremented for every valid-sized packet with an incorrect FCS value.

D31:12	R	Reset = Read as 0	Reserved
D11:00	R/W	Reset = 0x000	TFCS

Transmit oversize frame counter (A060 0724)
Incremented for each transmitted frame that exceeds 1518 bytes (NON_VLAN) or 1522 bytes (VLAN) and contains a valid FCS.

D31:12	R	Reset = Read as 0	Reserved
D11:00	R/W	Reset = 0x000	TOVR

Transmit undersize frame counter (A060 0728)
Incremented for every frame less than 64 bytes, with a correct FCS value. This counter also is incremented when a jumbo packet is aborted (see "TXAJ" on page 356) and the MAC is not checking the FCS (see "CRCEN" on page 363), because the frame is reported as having a length of 0 bytes.

D31:12	R	Reset = Read as 0	Reserved
D11:00	R/W	Reset = 0x000	TUND

Transmit fragment counter (A060 072C)
Incremented for every frame less than 64 bytes, with an incorrect FCS value.

D31:12	R	Reset = Read as 0	Reserved
D11:00	R/W	Reset = 0x000	TFRG

General Statistics registers

Table 236 lists the General Statistics registers.

Address	Register	General registers	R/W
A060_0730	CAR1	Carry Register 1	R
A060_0734	CAR2	Carry Register 2	R
A060_0738	CAM1	Carry Register 1 Mask register	R/W
A060_073C	CAM2	Carry Register 2 Mask register	R/W

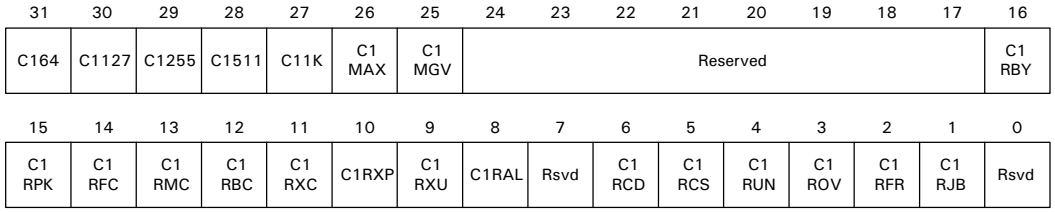
Table 236: General Statistics register address map

Carry Register 1 (CAR1) and Carry Register 2 (CAR2) have carry bits for all of the statistics counters. These carry bits are set when the associated counter reaches a rollover condition.

These carry bits also can cause the STOVFL (statistics counter overflow) bit in the Ethernet Interrupt Status register (see "Ethernet Interrupt Status register" on page 396) to be set. Carry Register 1 Mask register (CAM1) and Carry Register 2 Mask register (CAM2) have individual mask bits for each of the carry bits. When set, the mask bit prevents the associated carry bit from setting the STOVFL bit.

Carry Register 1

Address: A060 0730



Bits	Access	Mnemonic	Reset	Description
D31	R/C	C164	0	Carry register 1 TR64 counter carry bit
D30	R/C	C1127	0	Carry register 1 TR127 counter carry bit
D29	R/C	C1255	0	Carry register 1 TR255 counter carry bit
D28	R/C	C1511	0	Carry register TR511 counter carry bit
D27	R/C	C11K	0	Carry register 1 TR1K counter carry bit
D26	R/C	C1MAX	0	Carry register 1 TRMAX counter carry bit
D25	R/C	C1MGV	0	Carry register 1 TRMGV counter carry bit
D24:17	N/A	Reserved	N/A	N/A
D16	R/C	C1RBY	0	Carry register 1 RBYT counter carry bit
D15	R/C	C1RPK	0	Carry register 1 RPKT counter carry bit
D14	R/C	C1RFC	0	Carry register 1 RFCS counter carry bit
D13	R/C	C1RMC	0	Carry register 1 RMCA counter carry bit
D12	R/C	C1RBC	0	Carry register 1 RBCA counter carry bit
D11	R/C	C1RXC	0	Carry register 1 RXCF counter carry bit
D10	R/C	C1RXP	0	Carry register 1 RXPF counter carry bit
D09	R/C	C1RXU	0	Carry register 1 RXUO counter carry bit
D08	R/C	C1RAL	0	Carry register 1 RALN counter carry bit
D07	N/A	Reserved	N/A	N/A
D06	R/C	C1RCD	0	Carry register 1 RCDE counter carry bit

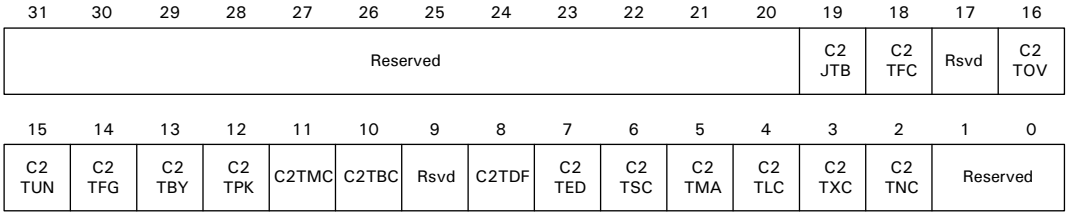
Table 237: Carry Register 1

Bits	Access	Mnemonic	Reset	Description
D05	R/C	C1RCS	0	Carry register 1 RCSE counter carry bit
D04	R/C	C1RUN	0	Carry register 1 RUND counter carry register
D03	R/C	C1ROV	0	Carry register 1 ROVR counter carry bit
D02	R/C	C1RFR	0	Carry register 1 RFRG counter carry bit
D01	R/C	C1RJB	0	Carry register 1 RJBR counter carry bit
D00	N/A	Reserved	N/A	N/A

Table 237: Carry Register 1

Carry Register 2

Address: A060 0734



Bits	Access	Mnemonic	Reset	Description
D31:20	N/A	Reserved	N/A	N/A
D19	R/C	C2TJB	0	Carry register 2 TJBR counter carry bit
D18	R/C	C2TFC	0	Carry register 2 TFCS counter carry bit
D17	N/A	Reserved	N/A	N/A
D16	R/C	C2TOV	0	Carry register 2 TOVR counter carry bit
D15	R/C	C2TUN	0	Carry register 2 TUND counter carry bit
D14	R/C	C2TFG	0	Carry register 2 TFRG counter carry bit
D13	R/C	C2TBY	0	Carry register 2 TBYT counter carry bit
D12	R/C	C2TPK	0	Carry register 2 TPKT counter carry bit
D11	R/C	C2TMC	0	Carry register 2 TMCA counter carry bit

Table 238: Carry Register 2

Bits	Access	Mnemonic	Reset	Description
D10	R/C	C2TBC	0	Carry register 2 TBCA counter carry bit
D09	N/A	Reserved	N/A	N/A
D08	R/C	C2TDF	0	Carry register 2TDFR counter carry bit
D07	R/C	C2TED	0	Carry register 2 TEDF counter carry bit
D06	R/C	C2TSC	0	Carry register 2 TSCL counter carry bit
D05	R/C	C2TMA	0	Carry register 2 TMCL counter carry bit
D04	R/C	C2TLC	0	Carry register 2 TLCL counter carry bit
D03	R/C	C2TXC	0	Carry register 2 TXCL counter carry bit
D02	R/C	C2TNC	0	Carry register 2 TNCL counter carry bit
D01:00	N/A	Reserved	N/A	N/A

Table 238: Carry Register 2

Carry Register 1 Mask register

Address: A060 0738

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
M164	M1127	M 1255	M 1511	M C11K	M1 MAX	M1 MGV	Reserved								M1 RBY
15	**14**	**13**	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
M1 RPK	M1 RFC	M1 RMC	M1 RBC	M1 RXC	M1RXP	M1 RXU	M1RAL	Not used	M1 RCD	M1 RCS	M1 RUN	M1 ROV	M1 RFR	M1 RJB	Not used

Bits	Access	Mnemonic	Reset	Description
D31	R/W	M164	1	Mask register 1 TR64 counter carry bit mask
D30	R/W	M1127	1	Mask register 1 TR127 counter carry bit mask
D29	R/W	M1255	1	Mask register 1 TR255 counter carry bit mask
D28	R/W	M1511	1	Mask register 1 TR511 counter carry bit mask
D27	R/W	M11K	1	Mask register 1 TR1K counter carry bit mask
D26	R/W	M1MAX	1	Mask register 1 TRMAX counter carry bit mask

Table 239: Carry Register 1 Mask register

Bits	Access	Mnemonic	Reset	Description
D25	R/W	M1MGV	1	Mask register 1 TRMGV counter carry bit mask
D24:17	N/A	Reserved	N/A	N/A
D16	R/W	M1RBY	1	Mask register 1 RBYT counter carry bit mask
D15	R/W	M1RPK	1	Mask register 1 RPKT counter carry bit mask
D14	R/W	M1RFC	1	Mask register 1 RFCS counter carry bit mask. Set this bit to 1 for RMII applications.
D13	R/W	M1RMC	1	Mask register 1 RMCA counter carry bit mask
D12	R/W	M1RBC	1	Mask register 1 RBCA counter carry bit mask
D11	R/W	M1RXC	1	Mask register 1 RXCF counter carry bit mask
D10	R/W	M1RXP	1	Mask register 1 RXPF counter carry bit mask
D09	R/W	M1RXU	1	Mask register 1 RXUO counter carry bit mask
D08	R/W	M1RAL	1	Mask register 1 RALN counter carry bit mask. Set this bit to 1 for RMII applications.
D07	N/A	Not used	1	Always write as 1.
D06	R/W	M1RCD	1	Mask register 1 RCDE counter carry bit mask
D05	R/W	M1RCS	1	Mask register 1 RCSE counter carry bit mask
D04	R/W	M1RUN	1	Mask register 1 RUND counter carry bit mask
D03	R/W	M1ROV	1	Mask register 1 ROVR counter carry bit mask
D02	R/W	M1RFR	1	Mask register 1 RFRG counter carry bit mask
D01	R/W	M1RJB	1	Mask register 1 RJBR counter carry bit mask
D00	R/W	Not used	1	Always write as 1.

Table 239: Carry Register 1 Mask register

Carry Register 2 Mask register

Address: A060 073C

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Reserved												M2 JTB	M2 TFC	Not used	M2 TOV

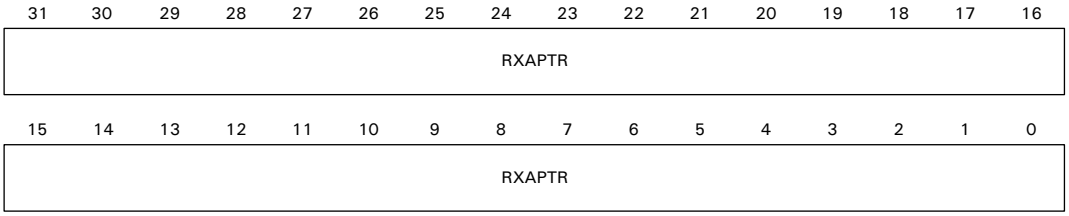
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
M2 TUN	M2 TFG	M2 TBY	M2 TPK	M2 TMC	M2TBC	Not used	M2TDF	M2 TED	M2 TSC	M2 TMA	M2 TLC	M2 TXC	M2 TNC	Not used	

Bits	Access	Mnemonic	Reset	Description
D31:20	N/A	Reserved	N/A	N/A
D19	R/W	M2TJB	1	Mask register 2 TJBR counter carry bit mask
D18	R/W	M2TFC	1	Mask register 2 TFCS counter carry bit mask
D17	R/W	Not used	1	Always write as 1.
D16	R/W	M2TOV	1	Mask register 2 TOVR counter carry bit mask
D15	R/W	M2TUN	1	Mask register 2 TUND counter carry bit mask
D14	R/W	M2TFG	1	Mask register 2 TFRG counter carry bit mask
D13	R/W	M2TBY	1	Mask register 2 TBYT counter carry bit mask
D12	R/W	M2TPK	1	Mask register 2 TPKT counter carry bit mask
D11	R/W	M2TMC	1	Mask register 2 TMCA counter carry bit mask
D10	R/W	M2TBC	1	Mask register 2 TBCA counter carry bit mask
D09	R/W	Not used	1	Always write as 1.
D08	R/W	M2TDF	1	Mask register 2 TDFR counter carry bit mask
D07	R/W	M2TED	1	Mask register 2 TEDF counter carry bit mask
D06	R/W	M2TSC	1	Mask register 2 TSCL counter carry bit mask
D05	R/W	M2TMA	1	Mask register 2 TMCL counter carry bit mask
D04	R/W	M2TLC	1	Mask register 2 TLCL counter carry bit mask
D03	R/W	M2TXC	1	Mask register 2 TXCL counter carry bit mask
D02	R/W	M2TNC	1	Mask register 2 TNCL counter carry bit mask
D01:00	R/W	Not used	11	Always write as “11.”

Table 240: Carry Register 2 Mask register

RX_A Buffer Descriptor Pointer register

Address: A060 0A00



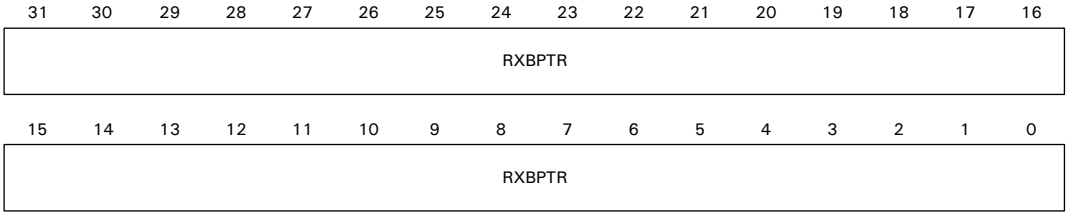
Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:00	R/W	RXAPTR	0x00000000	**RX_A Buffer Descriptor Pointer** Contains a pointer to the initial receive buffer descriptor for the A pool of buffers.

Table 241: RX_A Buffer Descriptor Pointer register

RX_B Buffer Descriptor Pointer register

Address: A060 0A04



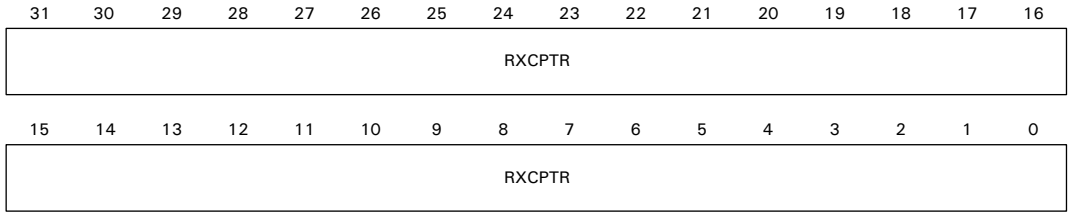
Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:00	R/W	RXBPTR	0x00000000	**RX_B Buffer Descriptor Pointer** Contains a pointer to the initial receive buffer descriptor for the B pool of buffers.

Table 242: RX_B Buffer Descriptor Pointer register

RX_C Buffer Descriptor Pointer register

Address: A060 0A08



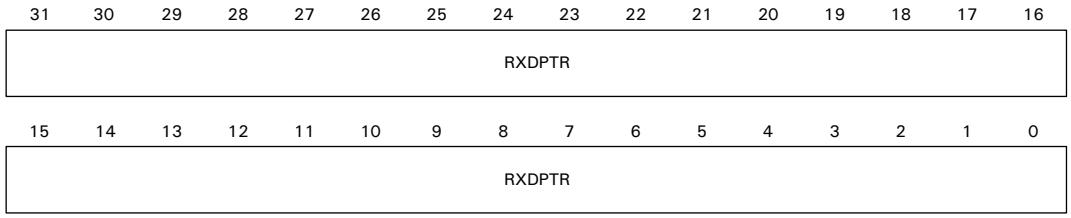
Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:00	R/W	RXCPTR	0x00000000	**RX_C Buffer Descriptor Pointer** Contains a pointer to the initial receive buffer descriptor for the C pool of buffers.

Table 243: RX_C Buffer Descriptor Pointer

RX_D Buffer Descriptor Pointer register

Address: A060 0A0C



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:00	R/W	RXDPTR	0x00000000	**RX_D Buffer Descriptor Pointer** Contains a pointer to the initial receive buffer descriptor for the D pool of buffers.

Table 244: RX_D Buffer Descriptor Pointer register

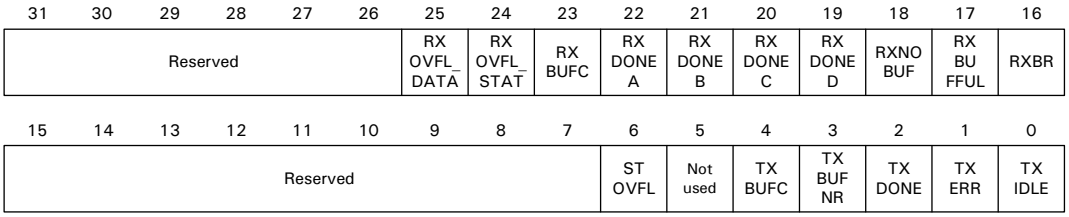
Ethernet Interrupt Status register

Address: A060 0A10

The Ethernet Interrupt Status register contains status bits for all of the Ethernet interrupt sources. Each interrupt status bit is assigned to either the RX or TX Ethernet interrupt; bits D25:16 are assigned to the RX interrupt and D06:00 are assigned to the TX interrupt.

The bits are set to indicate an interrupt condition, and are cleared by writing a 1 to the appropriate bit. All interrupts bits are enabled using the Ethernet Interrupt Enable register (EINTREN). If any enabled bit in the Ethernet Interrupt Status register is set, its associated Ethernet interrupt to the system is set. The interrupt to the system is negated when all active interrupt sources have been cleared. If an interrupt source is active at the same time the interrupt bit is being cleared, the interrupt status bit remains set and the interrupt signal remains set.

Note: For diagnostics, software can cause any of these interrupt status bits to be set by writing a 1 to a bit that is 0.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:26	N/A	Reserved	N/A	N/A
D25	R/C	RXOVFL_DATA	0	Assigned to RX interrupt. RX data FIFO overflowed. For proper operation, reset the receive packet processor using the ERX bit in the Ethernet General Control register when an overflow condition occurs.

Table 245: Ethernet Interrupt Status register

Bits	Access	Mnemonic	Reset	Description
D24	R/C	RXOVFL_STAT	0	Assigned to RX interrupt. RX status FIFO overflowed.
D23	R/C	RXBUFC	0	Assigned to RX interrupt. I bit set in receive Buffer Descriptor and buffer closed.
D22	R/C	RXDONEA	0	Assigned to RX interrupt. Complete receive frame stored in pool A of system memory.
D21	R/C	RXDONEB	0	Assigned to RX interrupt. Complete receive frame stored in pool B of system memory.
D20	R/C	RXDONEC	0	Assigned to RX interrupt. Complete receive frame stored in pool C of system memory.
D19	R/C	RXDONED	0	Assigned to RX interrupt. Complete receive frame stored in pool D of system memory.
D18	R/C	RXNOBUF	0	Assigned to RX interrupt. No buffer is available for this frame due to one of these conditions: ■ All four buffer rings being disabled ■ All four buffer rings being full ■ No available buffer big enough for the frame
D17	R/C	RXBUFFUL	0	Assigned to RX interrupt. No buffer is available for this frame because all four buffer rings are disabled or full.
D16	R/C	RXBR	0	Assigned to RX interrupt. New frame available in the RX_FIFO. This bit is used for diagnostics.
D15:07	N/A	Reserved	N/A	N/A

Table 245: Ethernet Interrupt Status register

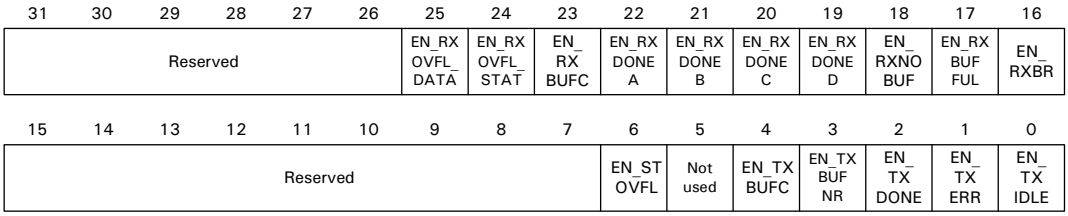
Bits	Access	Mnemonic	Reset	Description
D06	R/C	STOVFL	0	Assigned to TX interrupt. Statistics counter overflow. Individual counters can be masked using the Carry Register 1 and 2 Mask registers. The source of this interrupt is cleared by clearing the counter that overflowed, and by clearing the associated carry bit in either Carry Register 1 or Carry Register 2 by writing a 1 to the bit.
D05	R	Not used	0	Always write as 0.
D04	R/C	TXBUFC	0	Assigned to TX interrupt. I bit set in the Transmit Buffer Descriptor and buffer closed.
D03	R/C	TXBUFNR	0	Assigned to TX interrupt. F bit not set in the Transmit Buffer Descriptor when read from the TX Buffer descriptor RAM.
D02	R/C	TXDONE	0	Assigned to TX interrupt. Frame transmission complete.
D01	R/C	TXERR	0	Assigned to TX interrupt. Last frame not transmitted successfully. See "Ethernet Interrupt Status register" on page 396 for information about restarting the transmitter when this bit is set.
D00	R/C	TXIDLE	0	Assigned to TX interrupt. TX_WR logic has no frame to transmit. See "Ethernet Interrupt Status register" on page 396 for information about restarting the transmitter when this bit is set.

Table 245: Ethernet Interrupt Status register

Ethernet Interrupt Enable register

Address: A060 0A14

The Ethernet Interrupt Enable register contains individual enable bits for each of the bits in the Ethernet Interrupt Status register. When these bits are cleared, the corresponding bit in the Ethernet Interrupt Status register cannot cause the interrupt signal to the system to be asserted when it is set.



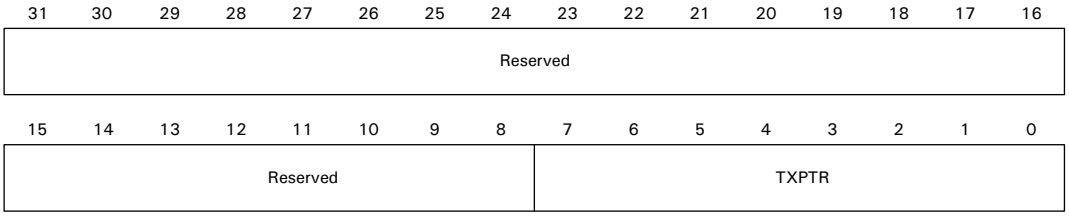
Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:26	N/A	Reserved	N/A	N/A
D25	R/W	EN_RXOVFL_DATA	0	Enable the RXOVFL_DATA interrupt bit.
D24	R/W	EN_RXOVFL_STAT	0	Enable the RXOVFL_STATUS interrupt bit.
D23	R/W	EN_RXBUFC	0	Enable the RXBUFC interrupt bit.
D22	R/W	EN_RXDONEA	0	Enable the RXDONEA interrupt bit.
D21	R/W	EN_RXDONEB	0	Enable the RXDONEB interrupt bit.
D20	R/W	EN_RXDONEC	0	Enable the RXDONEC interrupt bit.
D19	R/W	EN_RXDONED	0	Enable the RXDONED interrupt bit.
D18	R/W	EN_RXNOBUF	0	Enable the RXNOBUF interrupt bit.
D17	R/W	EN_RXBUFFUL	0	Enable the RXBUFFUL interrupt bit.
D16	R/W	EN_RXBR	0	Enable the RXBR interrupt bit.
D15:07	N/A	Reserved	N/A	N/A
D06	R/W	EN_STOVFL	0	Enable the STOVFL interrupt bit.
D05	R/W	Not used	0	Always write as 0.
D04	R/W	EN_TXBUFC	0	Enable the TXBUFC interrupt bit.
D03	R/W	EN_TXBUFNR	0	Enable the TXBUFNR interrupt bit.
D02	R/W	EN_TXDONE	0	Enable the TXDONE interrupt bit.
D01	R/W	EN_TXERR	0	Enable the TXERR interrupt bit.
D00	R/W	EN_TXIDLE	0	Enable the TXIDLE interrupt bit.

Table 246: Ethernet Interrupt Enable register

TX Buffer Descriptor Pointer register

Address: A060 0A18



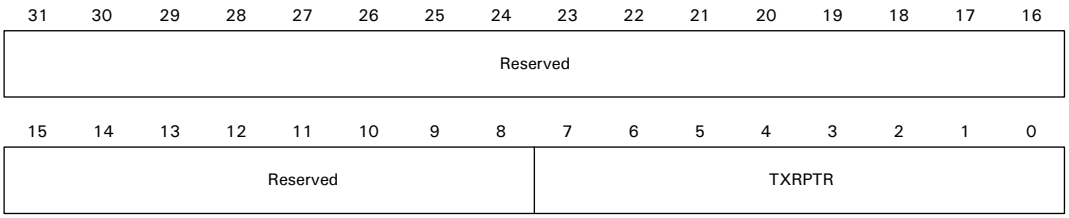
Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:08	N/A	Reserved	N/A	N/A
D07:00	R/W	TXPTR	0x00	Contains a pointer to the initial transmit buffer descriptor in the TX buffer descriptor RAM. **Note:** This pointer is the 8-bit physical address of the TX buffer descriptor RAM, and points to the first location of the four-location buffer descriptor. The byte offset of this buffer descriptor can be calculated by multiplying this value by 4.

Table 247: TX Buffer Descriptor Pointer register

Transmit Recover Buffer Descriptor Pointer register

Address: A060 0A1C



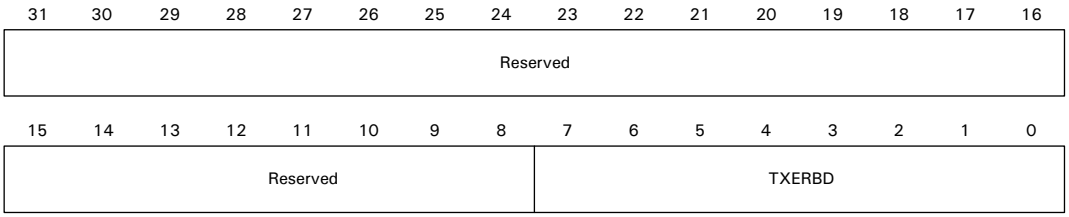
Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:08	N/A	Reserved	N/A	N/A
D07:00	R/W	TXRPTR	0x00	Contains a pointer to a buffer descriptor in the TX buffer descriptor RAM. **Note:** This pointer is the 8-bit physical address of the TX buffer descriptor RAM, and points to the first location of the four-location buffer descriptor. The byte offset of this buffer descriptor can be calculated by multiplying this value by 4. This is the buffer descriptor at which the TX_WR logic resumes processing when TCLER is toggled from low to high in Ethernet General Control Register #2 (see page 352).

Table 248: Transmit Recover Buffer Descriptor Pointer register

TX Error Buffer Descriptor Pointer register

Address: A060 0A20



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:08	N/A	Reserved	N/A	N/A

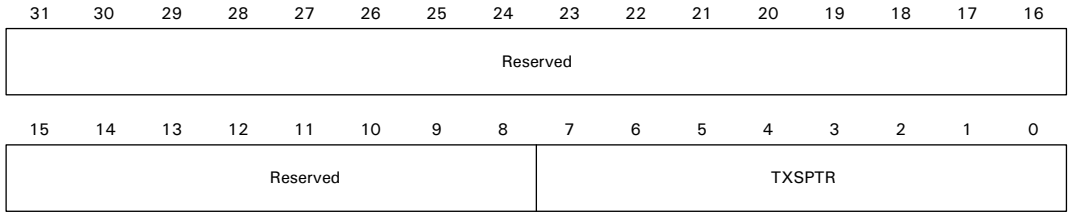
Table 249: TX Error Buffer Descriptor Pointer register

Bits	Access	Mnemonic	Reset	Description
D07:00	R	TXERBD	0x00	Contains the pointer (in the TX buffer descriptor RAM) to the last buffer descriptor of a frame that was not successfully transmitted. TXERBD is loaded by the TX_WR logic when a transmit frame is aborted by the MAC or when the MAC finds a CRC error in a frame. TXERBD also is loaded if a buffer descriptor that is not the first buffer descriptor in a frame does not have its F bit set. **Note:** This pointer is the 8-bit physical address of the TX buffer descriptor RAM, and points to the first location of the four-location buffer descriptor. The byte offset of this buffer descriptor can be calculated by multiplying this value by 4. **Note:** Software uses TXERBD to identify frames that were not transmitted successfully.

Table 249: TX Error Buffer Descriptor Pointer register

TX Stall Buffer Descriptor Pointer register

Address: A060 0A24



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:08	N/A	Reserved	N/A	N/A

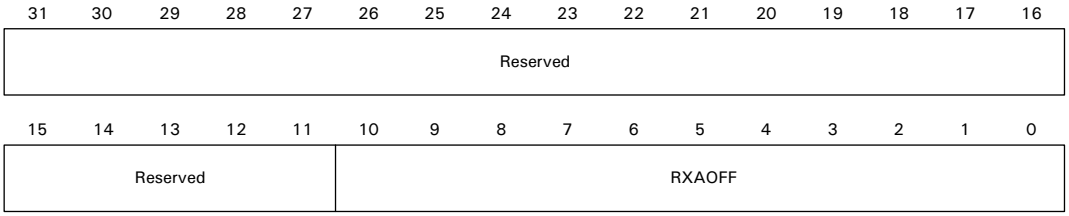
Table 250: TX Stall Buffer Descriptor Pointer register

Bits	Access	Mnemonic	Reset	Description
D07:00	R	TXSPTR	0x00	If the TX runs out of frames to send, it sets TXIDLE in the Ethernet Interrupt Status register and stores the pointer (in the TX buffer descriptor RAM) to the buffer descriptor that did not have its F bit set in the TX Stall Buffer Descriptor Pointer register. **Note:** This pointer is the 8-bit physical address of the TX buffer descriptor RAM, and points to the first location of the four-location buffer descriptor. The byte offset of this buffer descriptor can be calculated by multiplying this value by 4. **Note:** Software uses TXSPTR to identify the entry in the TX buffer descriptor RAM at which the TX stalled.

Table 250: TX Stall Buffer Descriptor Pointer register

RX_A Buffer Descriptor Pointer Offset register

Address: A060 0A28



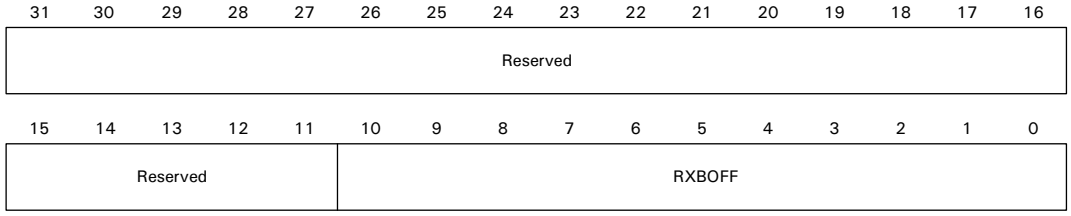
Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:11	N/A	Reserved	N/A	N/A
D10:00	R	RXAOFF	0x000	Contains an 11-bit byte offset from the start of the pool A ring. The offset is updated at the end of the RX packet, and will have the offset to the next buffer descriptor that will be used. RXAOFF can be used to determine where the RX_RD logic will put the next packet.

Table 251: RX_A Buffer Descriptor Pointer Offset register

RX_B Buffer Descriptor Pointer Offset register

Address: A060 0A2C



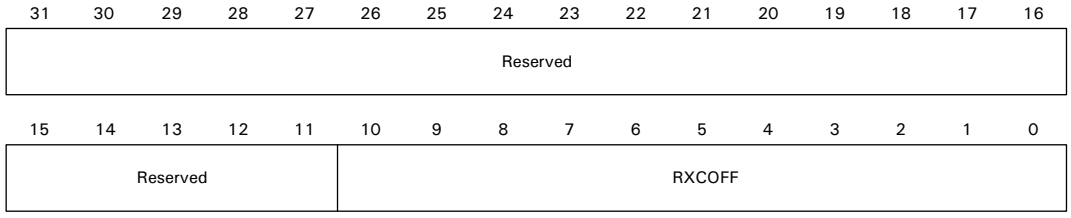
Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:11	N/A	Reserved	N/A	N/A
D10:00	R	RXBOFF	0x000	Contains an 11-bit byte offset from the start of the pool B ring. The offset is updated at the end of the RX packet, and will have the offset to the next buffer descriptor that will be used. RXBOFF can be used to determine where the RX_RD logic will put the next packet.

Table 252: RX_B Buffer Descriptor Pointer Offset register

RX_C Buffer Descriptor Pointer Offset register

Address: A060 0A30



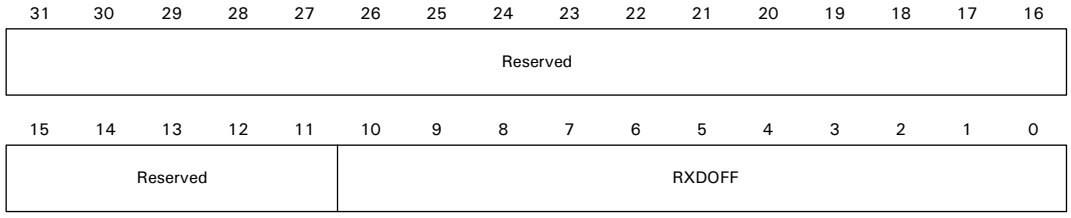
Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:11	N/A	Reserved	N/A	N/A
D10:00	R	RXCOFF	0x000	Contains an 11-bit byte offset from the start of the pool C ring. The offset is updated at the end of the RX packet, and will have the offset to the next buffer descriptor that will be used. RXCOFF can be used to determine where the RX_RD logic will put the next packet.

Table 253: RX_C Buffer Descriptor Pointer Offset register

RX_D Buffer Descriptor Pointer Offset register

Address: A060 0A34



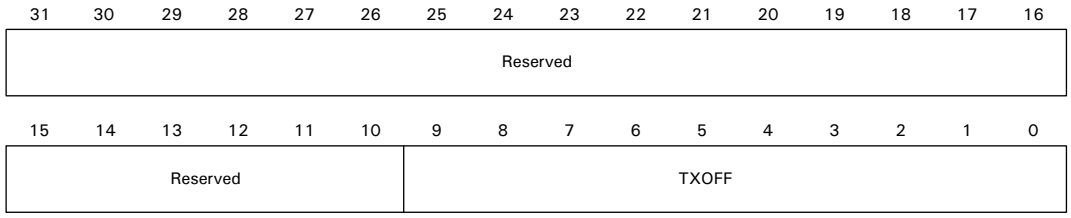
Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:11	N/A	Reserved	N/A	N/A
D10:00	R	RXDOFF	0x000	Contains an 11-bit byte offset from the start of the pool D ring. The offset is updated at the end of the RX packet, and will have the offset to the next buffer descriptor that will be used. RXDOFF can be used to determine where the RX_RD logic will put the next packet.

Table 254: RX_D Buffer Descriptor Pointer Offset register

Transmit Buffer Descriptor Pointer Offset register

Address: A060 0A38



Register bit assignment

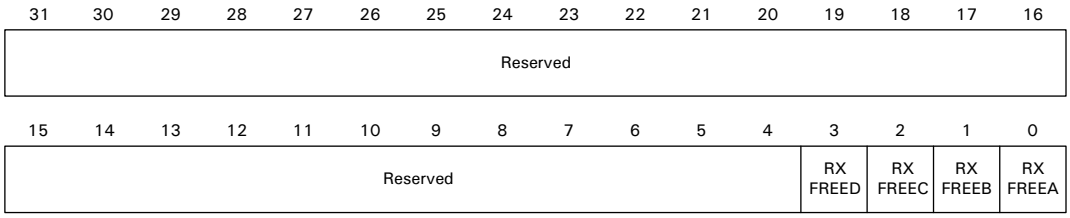
Bits	Access	Mnemonic	Reset	Description
D31:10	N/A	Reserved	N/A	N/A
D09:00	R	TXOFF	0x000	Contains a 10-bit byte offset from the start of the transmit ring in the TX buffer descriptor RAM. The offset is updated at the end of the TX packet, and will have the offset to the next buffer descriptor that will be used. TXOFF can be used to determine from where the TX_WR logic will grab the next packet.

Table 255: TX Buffer Descriptor Pointer Offset register

RX Free Buffer register

Address: A060 0A3C

So the RX_RD logic knows when the software is freeing a buffer for reuse, the software writes to the RXFREE register each time it frees a buffer in one of the pools. RXFREE has an individual bit for each pool; this bit is set to 1 when the register is written. Reads to RXFREE always return all 0s.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:04	N/A	Reserved	N/A	N/A
D03	W	RXFREED	0	Pool D free bit
D02	W	RXFREEC	0	Pool C free bit
D01	W	RXFREEB	0	Pool B free bit
D00	W	RXFREEA	0	Pool A free bit

Table 256: RX Free Buffer register

TX buffer descriptor RAM

Address: A060 1000

The TX buffer descriptor RAM holds 64 transmit buffer descriptors on-chip. Each buffer descriptor occupies four locations in the RAM, and the RAM is implemented as a 256x32 device. This is the format of the TX buffer descriptor RAM:

Offset + 0

D31:00	R/W	Source address

Offset + 4

D31:11	R/W	Not used
D10:00	R/W	Buffer length

Offset + 8

D31:00	R/W	Destination address (not used)

Offset + C

D31	R/W	W	Wrap
D30	R/W	I	Interrupt on buffer completion
D29	R/W	L	Last buffer on transmit frame
D28	R/W	F	Buffer full
D27:16	R/W	Reserved	N/A
D15:00	R/W	Status	Transmit status from MAC

See Figure 68, "Transmit buffer descriptor format," on page 337, for more information about the fields in *Offset+C*.

Sample hash table code

This sample C code describes how to calculate hash table entries based on 6-byte Ethernet destination addresses and a hash table consisting of two 32-bit registers (HT1 and HT2). HT1 contains locations 31:0 of the hash table; HT2 contains locations 63:32 of the hash table.

The pointer to the hash table is bits [28:23] of the Ethernet destination address CRC. The polynomial is the same as that used for the Ethernet FCS:

```
G(x) = x^32+x^26+x^23+x^22+x^16+x^12+x^11+x^10+x^8+x^7+x^5+x^4+x^2+x+1


static ETH_ADDRESS mca_address[MAX_MCA];   /*list of MCA addresses*/
static INT16 mca_count;                /*# of MCA addresses*/

/  *
   *
   * Function: void eth_load_mca_table (void)
   *
   * Description:
   *
   * This routine loads the MCA table. It generates a hash table for
   * the MCA addresses currently registered and then loads this table
   * into the registers HT1 and HT2.
   *
   * Parameters:
   *
   *    none
   *
   * Return Values:
   *
   *    none
   *
   */

static void eth_load_mca_table (void)

{
        WORD32 has_table[2];
```

```
        // create hash table for MAC address
        eth_make_hash_table (hash_table);

           (*MERCURY_EFE) .ht2.bits.data = SWAP32(hash_table[1]);
           (*MERCURY_EFE) .ht1.bits.data = SWAP32(hash_table[0]);
}


/  *
   *
   * Function: void eth_make_hash_table (WORD32 *hash_table)
   *
   * Description:
   *
   *       This routine creates a hash table based on the CRC values of
   *       the MAC addresses setup by set_hash_bit(). The CRC value of
   *       each MAC address is calculated and the lower six bits are used
   *       to generate a value between 0 and 64. The corresponding bit in
   *       the 64-bit hash table is then set.
   *
   *    Parameters:
   *
   *       hash_table           pointer to buffer to store hash table in.
   *
   * Return Values:
   *
   *       none
   *
   */

static void eth_make_hash_table (WORD32 *hash_table)

{
        int index;

        memset (hash_table, 0, 8);               /* clear hash table*/

        for (index = 0; index < mca_count; index++)/*for each mca address*/
```

```
        {
           set_hash_bit ((BYTE *) hash_table, calculate_hash_bit (mca_address
           [index]));
        }
}


/  *
   *
   * Function: void set_hash_bit (BYTE *table, int bit)
   *
   * Description:
   *
   *       This routine sets the appropriate bit in the hash table.
   *
   * Parameters:
   *
   *       table             pointer to hash table
   *       bit               position of bit to set
   *
   * Return Values:
   *
   *       none
   *
   */

static void set_hash_bit (BYTE *table, int bit)

{
        int byte_index, bit_index;

        byte-index = bit >> 3;
        bit_index = bit & 7;
        table [byte_index] |= (1 << bit_index);
}


/  *
   *
```

```
   * Function: int calculate_hash_bit (BYTE *mca)
   *
   * Description:
   *       This routine calculates which bit in the CRC hash table needs
   *       to be set for the MERCURY to recognize incoming packets with
   *       the MCA passed to us.
   *
   * Parameters:
   *
   *       mca               pointer to multi-cast address
   *
   * Return Values:
   *
   *       bit position to set in hash table
   *
   */

#define POLYNOMIAL 0x4c11db6L

static int calculate_hash_bit (BYTE *mca)

{
        WORD32 crc;
        WORD16 *mcap, bp, bx;
        int result, index, mca_word, bit_index;
        BYTE lsb;
        WORD16 copy_mca[3]
        memcpy (copy_mca,mca,sizeof(copy_mca));
        for (index = 0; index < 3; index++)
        {
           copy_mca [index] = SWAP16 (copy_mca [index]);
        }

        mcap = copy_mca;
        crc = 0xffffffffL;

        for (mca_word = 0; mca_word < 3; mca_word++)
        {
           bp = *mcap;
```

```
      mcap++;
      for (bit_index = 0; bit_index < 16; bit_index++)
      {
            bx = (WORD16) (crc >> 16);       /* get high word of crc*/
            bx = rotate (bx, LEFT, 1);       /* bit 31 to lsb*/
            bx ^= bp;                        /* combine with incoming*/
            crc <<= 1;                       /* shift crc left 1 bit*/
            bx &= 1;                         /* get control bit*/
            if (bx)                          /* if bit set*/
            {
             crc ^= POLYNOMIAL;              /* xero crc with polynomial*/
            }
            crc |= bx:                       /* or in control bit*/
            bp = rotate (bp, RIGHT, 1);
      }
   }

   // CRC calculation done. The 6-bit result resides in bit
   // locations 28:23

   result = (crc >> 23) & 0x3f;

   return result;

}
```

PCI-to-AHB Bridge

CHAPTER 7

The PCI-to-AHB bridge provides connections between PCI-based modules/devices and the NS9775 AHB bus.

Important: This chapter presumes knowledge of PCI system standards and architecture, and explains how PCI works in relation to the AHB bus. If you have questions regarding PCI terminology or concepts, please refer to your PCI documentation.

About the PCI-to-AHB Bridge

The PCI-to-AHB bridge provides these features:

- Supports PCI specification 2.1 and 2.2 protocol
- AHB master and slave interfaces
- PCI master and target interfaces
- Open drain interrupt output for PCI bus
- Interrupt to AHB bus for AHB and PCI bus errors
- Supports 32-bit address and data on both busses
- Supports AHB core clock up to 100 MHz, and a PCI core clock of 33 MHz
- Performs all AHB-to-PCI reads as SPLIT transactions on the AHB bus (improves bus use)
- Supports AHB burst transfers up to 8 words
- AHB master supports all AHB slave responses for upstream (initiated on the PCI bus) PCI-to-AHB traffic
- Supports early burst termination on the AHB bus
- Dual 64-byte write buffers in both directions
- Single 64-byte read buffers in both directions
- Supports PCI configuration cycles
- Supports target retry, target disconnect, and target abort on PCI bus
- Supports all PCI parity generation and parity error detection
- Includes all PCI-specific configuration registers
- Supports configuration of internal PCI configuration registers using the AHB bus
- Supports PCI-to-AHB address translation
- Supports AHB-to-PCI address translation

Note: Use the AHB DMA function to move blocks of data between the ARM CPU and the PCI bus. Do not use load and store multiple commands to the PCI-to- AHB bridge and do not cache PCI memory.

PCI-to-AHB bridge functionality

Figure 72 shows the PCI-to-AHB bridge. *Downstream* transactions are those initiated on the AHB bus; *upstream* transactions are those initiated on the PCI bus.

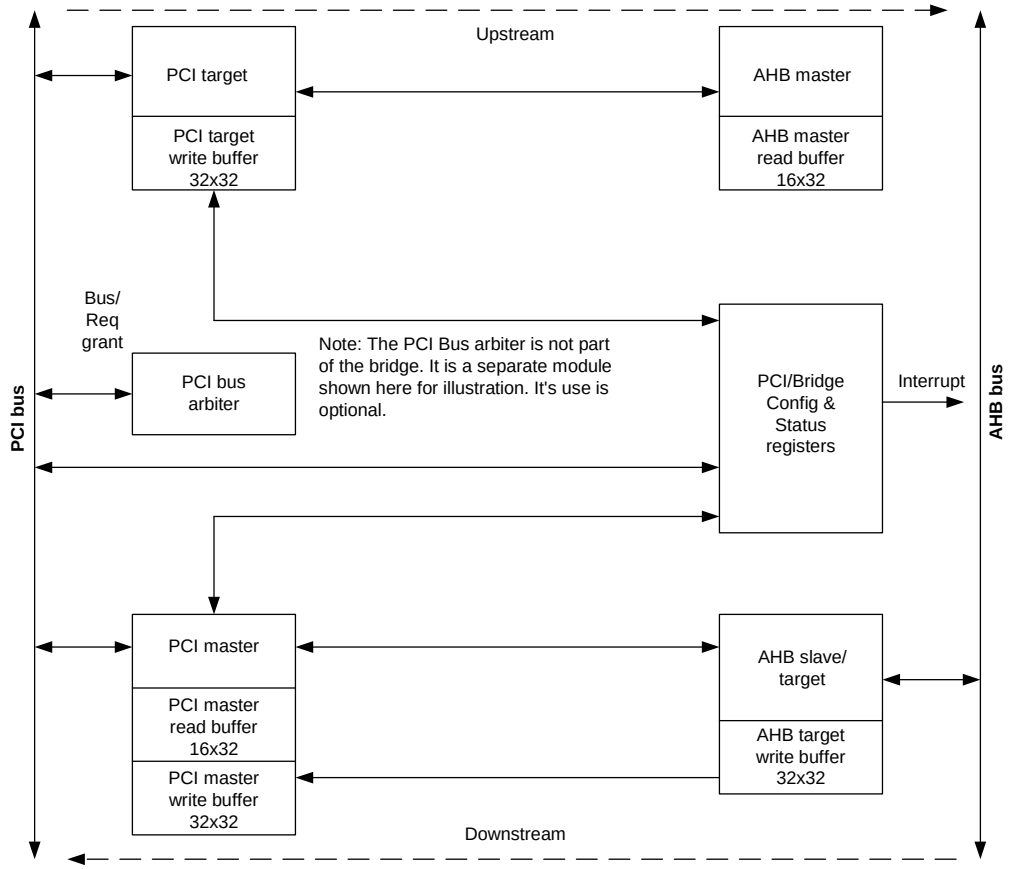


Figure 72: PCI-to-AHB bridge diagram

AHB master interface

The AHB master interface block controls the bridge's access to the AHB bus as a master, and is used for reads and writes to the AHB bus that are initiated on the PCI bus by an external PCI bus master. The requests are transferred to the AHB master from the PCI target interface. PCI writes are posted in the dual 64-byte PCI target write buffer. AHB read data is stored in the 64-byte AHB master read buffer before

being sent back to the PCI bus. The AHB master interface supports both single and burst transactions.

AHB slave/target interface

The AHB slave/target interface block controls the AHB target access to the bridge, and is used for reads and writes to the PCI bus that are initiated on the AHB bus. The requests are transferred to the PCI master interface. Writes are posted in the dual 64-byte AHB target write buffer and then transferred to the dual 64-byte PCI master write buffer. Reads are delayed through the AHB SPLIT transaction protocol. Read data is stored in the 64-byte PCI master read buffer. The AHB slave/target interface supports both single and burst transactions.

The AHB slave provides the AHB interface to the PCI/Bridge configuration registers (see page 423), using the `CONFIG_ADDR` and `CONFIG_DATA` memory spaces.

PCI target interface

The PCI target interface block controls the PCI bus access to the AHB bus, and is used for reads and writes that are initiated on the PCI bus by an external PCI bus master. The requests are transferred to the AHB master interface. Writes are posted in the dual 64-byte PCI target write buffer. The PCI target interface supports both single and burst transactions.

PCI master interface

The PCI master interface block controls the bridge's access to the PCI bus as a master, and is used for reads and writes to the PCI bus that are initiated on the AHB bus. The PCI master interfaces to the AHB slave/target interface, and receives its requests from the AHB target interface. The PCI master has both a 64-byte read buffer and a dual 64-byte write buffer. Both single and burst transactions are supported.

PCI/bridge configuration and status registers

The PCI/bridge configuration and status registers block contains standard PCI configuration and status registers. All registers can be accessed using the PCI and AHB buses (see "Configuration registers," beginning on page 423).

PCI bus arbiter

The PCI bus arbiter (also referred to as *PCI arbiter*), although embedded in NS9775, is not part of the PCI-to-AHB bridge protocol. See "PCI bus arbiter," beginning on page 431, for information about the PCI arbiter. The arbiter's use is optional.

Cross-bridge transaction error handling

The PCI-to-AHB bridge supports several error-handling mechanisms. All mechanisms can cause an interrupt to the system unless they are masked. Table 257 describes the errors and resulting action.

Error	Action taken
PCI-to-AHB write A write to the AHB bus does not complete due to receipt of an AHB bus error	■ The AHBERR bit in the PCI Bridge Interrupt Status register is set. ■ The AHB address is stored in the AHB Error Address register in the bridge.
PCI-to-AHB read A read to the AHB bus does not complete due to receipt of an AHB bus error	■ The AHBERR bit in the PCI Bridge Interrupt Status register is set. ■ The AHB address is stored in the AHB Error Address register in the bridge. ■ A PCI target abort is issued to release the PCI bus ■ The SIGNALED TARGET ABORT bit in the PCI Status register is set.
AHB-to-PCI write A write to the PCI bus does not complete due to receipt of a PCI bus error.	■ Bits [15:11] and [04] in the PCI Status register will indicate the source of the PCI bus error. ■ The PCI address is stored in the PCI Error Address register in the bridge.
AHB-to-PCI read A read to the PCI bus does not complete due to receipt of a PCI bus error.	■ Bits [15:11] and [04] in the PCI Status register will indicate the source of the PCI bus error ■ The PCI address is stored in the PCI Error Address register in the bridge.

Table 257: PCI-to-AHB error handling

PCI target error filtering

If the PCI target address or data parity checking logic finds an error during upstream transactions, the transaction is not passed to the AHB master. In this situation, the DETECTED PARITY ERROR bit in the PCI Status register is set. For address parity errors, the SIGNALED TARGET ABORT bit in the PCI Status register is set.

For data parity checking on writes, the entire burst is discarded if any word in the burst has a parity error.

AHB address decoding and translation

The PCI-to-AHB bridge supports these four AHB address spaces:

- PCI memory (0x8000_0000->0x8FFF_FFFF; 256 MB)
- PCI IO (0xA000_0000->0xA00F_FFFF; 1 MB)
- PCI CONFIG_ADDR register (0xA010_0000)
- PCI CONFIG_DATA register (0xA020_0000)

The bridge supports AHB to PCI memory address translation using the PCI Bridge AHB to PCI Memory Address Translate 0/1 (see page 449 and page 450) and PCI Bridge Address Translation Control (see page 453) registers. The address translation scheme breaks the 256 MB memory window from AHB to PCI into eight 32 MB subwindows that can be translated individually.

The PALTxVAL fields in the PCI Bridge AHB to PCI Memory Address Translate 0/1 registers control the translation for each of the eight subwindows. For example, if PALT0VAL is set to 0x75, an access to 0x8000_0000 on the AHB bus is mapped to 0xEA00_0000 in the PCI bus. The PALT_EN bit in the PCI Bridge Address Translation Control register determines whether AHB to PCI address translation is enabled:

- When set to 1, PALT_EN enables address translation.
- When set to 0, no address translation takes place, and the AHB and PCI addresses are identical.

Address translation also is provided for accesses to PCI IO space from the AHB bus. The translation process is similar to memory address translation, with this exception: the PALT8VAL field translates the 1 MB window dedicated to PCI IO space to another 1 MB IO window on the PCI bus. When PALT_EN is set to 1, IO translation is enabled.

PCI address decoding and mapping

The PCI-to-AHB bridge uses six Base Address registers (BAR), defined in the PCI Configuration register (see Table 260, “PCI/bridge configuration registers,” on page 425), to determine the range of PCI addresses to which the bridge responds. The window size of each Base Address register is hardwired (see Table 263 on page 429), but each register can be enabled or disabled using the ENBAR0–ENBAR5 bits in the PCI Miscellaneous Support register (see page 438) in the PCI arbiter.

The bridge supports PCI to AHB memory address translation using the PCI Bridge PCI to AHB Memory Address Translate 0/1(see page 451) and PCI Bridge Address Translation Control (see page 453) registers. The address translation scheme provides a separate translation value for each of the six Base Address registers. The translation window size is the same as the size of the corresponding register.

The MALTxVAL fields in the PCI Bridge PCI to AHB Memory Address Translate 0/1 registers (see page 451 and page 452) control the translation for each of the six Base Address registers. For example, if MALT1VAL is set to 0x08, an access to 0xFC00_0000 on the PCI bus that hits Base Address register 1 is mapped to 0x2000_0000 on the AHB bus. The MALT_EN bit in the PCI Bridge Address Translation Control register determines whether PCI to AHB address translation is enabled:

- When set to 1, MALT_EN enables address translation.
- When set to 0, no address translation takes place, and the AHB and PCI addresses are identical.

The external PCI bus is allowed access only to NS9775’s system memory. The MALTxVAL values, therefore, should be programmed only to map addresses in the lower 2 GB of NS9775’s 4 GB address space (0x0000_0000 -> 0x7FFF_FFFF)

Interrupts

The bridge generates an interrupt to the AHB bus, for either AHB or PCI bus errors. An AHB bus error interrupt is generated when the AHB master receives an ERROR response to a transaction it initiated. The status bit for this interrupt, AHBERR, is in the PCI Bridge Interrupt Status register (see page 446).

A PCI bus error interrupt is generated for any of these PCI conditions:

- Address or data parity error detected (DPE, see "Detected parity error" on page 427)

- Bridge-generated system error (SERR#, see "Signaled system error" on page 427)
- Bridge receives a master abort (RMA, see "Received master abort" on page 427)
- Bridge receives a target abort (RTA, see "Received target abort" on page 427)
- Bridge signals a target abort (STA, see "Signaled target abort" on page 428)
- Bridge master finds a parity error on read data or detects the target asserting a master data parity error (PERR#, see "Master data parity error" on page 428) and the parity error response bit in the PCI Command register (see page 426) is set.

The PCI Status register (see page 427) contains the status bits for the interrupts caused by PCI bus errors.

Use the PCI Bridge Interrupt Enable register (see page 447) to enable or disable interrupt sources. Clearing an enable bit (setting the bit to 0) prevents the associated interrupt status bit from asserting the external interrupt to the system.

When an AHB bus error occurs, the AHB address that caused the bus error is saved in the AHB Address Error register (see "PCI Bridge AHB Error Address register" on page 445). Because multiple errors can occur before the software services the interrupt, no new addresses are saved in the register until AHBERR (in the PCI Bridge Interrupt Status register) is cleared.

When a PCI bus error occurs, the PCI address that caused the bus error is saved in the PCI Address Error register ("PCI Bridge PCI Error Address register" on page 446). Because multiple bus errors can occur before the software services the interrupt, no new addresses are saved in the register until all error bits are cleared in the PCI Status register.

The bridge can drive an interrupt to the PCI bus. This interrupt is driven from the INTA2PCI bit in the PCI Miscellaneous Support register (see page 438) in the PCI arbiter. This interrupt is used only in systems in which NS9775 is not processing PCI interrupts, and is set by software.

Transaction ordering

The AHB-to-PCI bridge maintains the request order in each direction. Transactions are sent to the destination bus in the order in which they are received on the source bus. No order is maintained between upstream and downstream transactions.

Endian configuration

The PCI bus is defined as little endian and the AHB bus can be defined as either Big or little endian. The PCI-to-AHB bridge supports byte-swapping only when the AHB bus is configured as a big endian bus. Byte-swapping is selected using the endian mode bit in the Miscellaneous System Configuration register (see "Miscellaneous System Configuration and Status register," beginning on page 169). Table 258 shows the byte-swapping scheme used.

PCI bus byte	AHB bus byte
Data[31:24]	AHB_Data[7:0]
Data[23:16]	AHB_Data[15:8]
Data[15:08]	AHB_Data[23:16]
Data[07:00]	AHB_Data[31:24]

Table 258: Big endian byte-swapping

Configuration registers

The Configuration registers within the PCI-to-AHB bridge are accessed using PCI configuration cycles. Two registers are used to access the configuration registers from the AHB side: Configuration Address Port (CONFIG_ADDR) and Configuration Address Data Port (CONFIG_DATA).

Table 259 describes the fields in the Configuration Address Port register. The Configuration Address Data Port register has no specific format; it contains the read or write configuration data.

Bits	Access	Mnemonic	Reset	Description
D31	R/W	ENABLE	0x0	**Enable translation** 0 Disabled (default) 1 Enabled Enables translation of a subsequent access to the CONFIG_DATA register to a PCI configuration cycle.
D30:24	N/A	Reserved	N/A	N/A
D23:16	R/W	BUS_NUMBER	0x00	**Target PCI bus number** ■ **Bus 0.** Considered a local bus, so a Type 0 configuration is performed. ■ **All other bus numbers.** Result in a Type 1 cycle that targets an external bus (that is, a bus on the other side of a PCI-to-PCI bridge).
D15:11	R/W	DEVICE_NUMBER	0x00	**Target PCI device number** For Type 0 cycles, the bridge uses this field to determine which bit of AD[31:11] is the only bit set during the configuration cycle on the PCI bus. This will be the bit that is connected to the IDSEL input of the device assigned to this device number. **Note:** This value must be 0 for internal registers. **Example:** If DEVICE_NUMBER = 0x01, AD[31:11] = 0x000002
D10:08	R/W	FUNCTION_NUMBER	0x0	**Target function number within PCI device** This value is 0x0 for all accesses to bridge registers. This value is mapped to AD[10:08] during the configuration cycle.

Table 259: CONFIG_ADDR register

Bits	Access	Mnemonic	Reset	Description
D07:02	R/W	REGISTER_NUMBER	0x00	**Target register address within the PCI** 32-bit register, whose value is mapped to AD[07:02] during the configuration cycle. **Example:** If the PCI Vendor ID register is being accessed, the REGISTER_NUMBER will be 0x00. (See Table 260, "PCI/bridge configuration registers," on page 425 for more information.)
D01:00	R/W	TYPE	0x0	**Type field** The value in this field must be 00 for Type 0 cycles and 01 for Type 1 cycles. This value is mapped to AD[01:00] during the configuration cycle.

Table 259: CONFIG_ADDR register

Bridge Configuration registers

Table 260 shows the standard PCI configuration registers that are supported by the PCI-to-AHB bridge. These registers can be 8-, 16-, or 32-bits wide, as indicated in the table. The size of the transfer on the AHB bus determines which bytes are written.

The registers are described briefly in this chapter. For more information about each register, see your PCI documentation.

Note: The register number refers to the `REGISTER_NUMBER` field in the Configuration Address Port register (see Table 259, "CONFIG_ADDR register," on page 424).

Register number	[31:24]	[23:16]	[15:08]	[07:00]
0x00	Device ID[1]		Vendor ID[1]	
0x01	Status		Command	
0x02	Class code[1]			Revision ID[1]
0x03	BIST	Header	Latency timer	Cache size

Table 260: PCI/bridge configuration registers

Register number	[31:24]	[23:16]	[15:08]	[07:00]
0x04	Base address 0			
0x05	Base address 1			
0x06	Base address 2			
0x07	Base address 3			
0x08	Base address 4			
0x09	Base address 5			
0x0A	CardBus CIS pointer			
0x0B	Subsystem ID[1]		Subsystem vendor ID[1]	
0x0C	Expansion ROM			
0x0D	Reserved			
0x0E	Reserved			
0x0F	Max_Lat[1]	Min_Gnt[1]	Interrupt pin[1]	Interrupt Line

1 These entries are standard read-only PCI configuration registers that are initialized using registers in the PCI arbiter (see "PCI bus arbiter," beginning on page 431).

Table 260: PCI/bridge configuration registers

PCI Vendor ID register

Read-only value. To change this value, use the VENDOR_ID field in the PCI Configuration 0 register in the PCI arbiter (see page 441).

PCI Device ID register

Read-only value. To change this value, use the DEVICE_ID field in the PCI Configuration 0 register in the PCI arbiter (see page 441).

PCI Command register

The default value of this register is 0x0000. Table 261 describes the register fields.

Bits	Description	Type
D15:10	Reserved	Hardwired to 0
D09	Fast back-to-back	Hardwired to 0; the device cannot generate fast back-to-back cycles.
D08	SERR#	R/W
D07	Address stepping	Hardwired to 0
D06	Parity error response	R/W
D05	VGA palette snooping	Hardwired to 0
D04	Master MWI (set to 0 for NS9775)	R/W
D03	Special cycle response	Hardwired to 0
D02	Bus master (set to 1 for NS9775)	R/W
D01	Memory enable (set to 1 for NS9775)	R/W
D00	IO enable (set to 0 for NS9775)	R/W

Table 261: Command register

PCI Status register

Table 262 describes the PCI Status register fields.

Bits	Access	Mnemonic	Reset	Description
D15	R/C	DPE	0	**Detected parity error** Device detected parity error. Used as an interrupt source to AHB bus.
D14	R/C	SERR#	0	**Signaled system error** Device generated system error (SERR#). Used as an interrupt source to AHB bus.
D13	R/C	RMA	0	**Received master abort** Master aborted transaction. Used as an interrupt source to AHB bus.
D12	R/C	RTA	0	**Received target abort** Master received target abort. Used as an interrupt source to AHB bus.

Table 262: PCI Status register

Bits	Access	Mnemonic	Reset	Description
D11	R/C	STA	0	**Signaled target abort** Master signaled the target abort as target. Used as an interrupt source to AHB bus.
D10:09	Hard-wired to 10	DEVSEL	10	**DEVSEL timing for target** 00 Fast 01 Medium 10 Slow 11 Reserved
D08	R/C	PERR#	0	**Master data parity error** The master detected a parity error and the following conditions exist: ■ Master initiated transaction ■ Master set PERR# (read) or detected PERR# asserted by target (write) ■ Parity error response bit set in the PCI Command register Used as an interrupt source to the AHB bus.
D07	Hard-wired to 1	FBBC	1	**Fast back-to-back capable** 0 No support 1 Support Device supports fast back-to-back transactions as a target only.
D06	N/A	Not used	0	Hardwired to 0.
D05	Hard-wired to 0	BS66	0	**66MHz capable** Bus speed: 0 33 MHz 1 66MHz
D04:00	N/A	Not used	0	Always set to 0.

Table 262: PCI Status register

PCI Revision ID register

Read-only value. To change this value, use the `REVISION_ID` field in the PCI Configuration 1 register in the PCI arbiter (see page 441).

PCI Class Code register

Read only value. To change this value, use the CLASS_CODE field in the PCI Configuration 1 register in the PCI arbiter (see page 441).

PCI Cache Size register

Read/write value that should always be set to 0x00. The bridge ignores this value.

PCI Latency Timer register

Read/write field programmed by the device driver.

PCI Header register

Read-only value, hardwired to 0x0.

PCI BIST register

Read-only value, hardwired to 0x0.

PCI Base Address registers [5:0]

The PCI-to-AHB bridge supports the six Base Address registers defined by PCI. Table 263 defines the memory space size decoded by each register.

Base Address register	Memory size decoded
0	256 MB
1	64 MB
2	16 MB
3	4 MB
4	1 MB
5	256 KB

Table 263: Base Address register decoding sizes

Each Base Address register is enabled using the ENBAR0–ENBAR5 bits in the PCI Miscellaneous Support register (see page 438) in the PCI arbiter. Note that the bridge

forces the four least significant bits (LSBs) of each Base Address register to 0x0. As such, PCI defines each register with the following characteristics:

- Memory space indicator
- Located anywhere in the 32-bit address space
- Not prefetchable

PCI CardBus CIS Pointer register

Read-only value, hardwired to 0x0.

PCI Subsystem Vendor ID register

Read-only value. To change this value, use the SUBVENDOR_ID field in the PCI Configuration 2 register (see page 442) in the PCI arbiter.

PCI Subsystem ID register

Read-only value. To change this value, use the SUBSYSTEM_ID field in the PCI Configuration 2 register (see page 442) in the PCI arbiter.

PCI Expansion ROM register

Read-only value, hardwired to 0x00000000.

PCI Interrupt Line register

Read/write value indicating to which line of an interrupt controller the PCI interrupt generated by the bridge is connected. This register is used only in those systems in which NS9775 is not handling PCI interrupts.

PCI Interrupt Pin register

Read-only value programmed using the INTERRUPT_PIN field in the PCI Configuration 3 register (see page 443) in the PCI arbiter. Set this value to 0x1 (default value) when NS9775 drives INTA#.

PCI Min Grant register

Read-only value programmed using the MIN_GRANT field in the PCI Configuration 3 register (see page 443) in the PCI arbiter.

PCI Max Latency register

Read-only value programmed using the MAX_LATENCY field in the PCI Configuration 3 register (see page 443) in the PCI arbiter.

PCI bus arbiter

NS9775 provides an embedded PCI bus arbiter that supports up to three external PCI masters and the internal PCI-to-AHB bridge. The arbiter uses a rotating priority scheme. An AHB slave is integrated with the PCI bus arbiter to access programmable registers, to support system configuration and error reporting.

NS9775 can be configured to use either the embedded PCI arbiter or an external arbiter through the bootstrap initialization scheme used during powerup (see "Bootstrap initialization" on page 139). The RTCK pin selects the source of the arbiter:

- The internal arbiter is used if RTCK = 1.
- If a pulldown resistor is placed on the RTCK bit, an external arbiter is used. When an external arbiter is used, the REQ#/GNT# (request/grant) signals for the internal PCI-to-AHB bridge are brought to external pins on NS9775 (see Figure 74, "System connections to NS9775 — External arbiter and central resources," on page 471).

PCI arbiter functional description

The PCI bus arbiter supports up to four PCI masters, including the PCI-to-AHB bridge, using the rotating priority scheme shown in Table 264. With rotating priority, the priority of a master depends on its relative position to the last granted master. After reset, the arbiter defaults to the PCI-to-AHB bridge having the highest priority.

Last granted master	Highest priority	2nd priority	3rd priority	Lowest priority	Parked master
PCI-to-AHB bridge	External master 1	External master 2	External master 3	PCI-to-AHB bridge	PCI-to-AHB bridge
External master 1	External master 2	External master 3	PCI-to-AHB bridge	External master 1	External master 1
External master 2	External master 3	PCI-to-AHB bridge	External master 1	External master 2	External master 2
External master 3	PCI-to-AHB bridge	External master 1	External master 2	External master 3	External master 3

Table 264: Rotating priority scheme

Each master has a set of REQ#/GNT# signals used for bus arbitration. The master asserts its REQ# when it needs to execute a bus transaction. The arbiter then asserts the GNT# to the requester with the highest priority. Until the bus is idle (that is, FRAME# and IRDY# are both inactive), the arbiter continually arbitrates and the asserted GNT# can change each clock cycle. One GNT# can be negated coincident with another GNT# being asserted in this situation. When the bus goes idle, the arbiter stops arbitrating and the master with the asserted GNT# is allowed to start a transaction.

If there are no new requesters when the current bus master completes its transaction, the bus ownership stays with the most recent bus master (*bus parking*). If a REQ# is asserted from any of the other masters, there must be a one clock cycle delay between the negation of the GNT# to the parked bus master and the assertion of the GNT# to the bus master requesting the bus. If the granted bus master does not start its bus transaction within 16 PCI clocks of the bus being idle, the PCI arbiter sets the PCIBRK_Mx bit for that master (in the PCI Arbiter Interrupt Status register; see page 436) and negates GNT#. The bus ownership can then be granted to one of the other bus masters. For the three external masters, REQ# from the broken master is ignored until the interrupt service routine re-enables it by toggling its PCIEN_Mx bit from low-to-high in the PCI Arbitration Configuration register (see page 435). (Although a broken master condition for the PCI-to-AHB bridge is logged using the PCIBRK_Mx bit, it is never taken out of service.) The PCIEN_Mx bits are also used to enable or disable the requests from the three external masters during normal operation.

Slave interface

The PCI bus arbiter slave interface supports single 32-bit transfers only.

The system can be configured such that all CSRs can be accessed using only "privileged mode" accesses (HPROT=xx1x) or only user mode accesses (HPROT=xx0x). Use internal register access mode bit 0 in the Miscellaneous System Configuration register to set access accordingly (see "Miscellaneous System Configuration and Status register" on page 169).

The slave generates a AHB bus error if the address is not aligned on a 32-bit boundary and Misaligned Bus Address Response Mode is set in the Miscellaneous System Configuration and Status register. Accesses to non-existent addresses also result in an AHB bus error response.

PCI Arbiter Configuration registers

Table 265 provides the PCI bus arbiter register map. All configuration registers must be accessed as 32-bit words and as single accesses only. No bursting is allowed.

Address Offset	Register	Description
0xA030 0000	PARBCFG	PCI Arbiter Configuration
0xA030 0004	PARBINT	PCI Arbiter Interrupt Status
0xA030 0008	PARBINTEN	PCI Arbiter Interrupt Enable
0xA030 000C	PMISC	PCI Miscellaneous Support
0xA030 0010	PCFG0	PCI Configuration 0
0xA030 0014	PCFG1	PCI Configuration 1
0xA030 0018	PCFG2	PCI Configuration 2
0xA030 001C	PCFG3	PCI Configuration 3
0xA030 0020	PAHBCFG	PCI Bridge Configuration
0xA030 0024	PAHBERR	PCI Bridge AHB Error Address
0xA030 0028	PCIERR	PCI Bridge PCI Error Address
0xA030 002C	PINTR	PCI Bridge Interrupt Status

Table 265: PCI arbiter register map

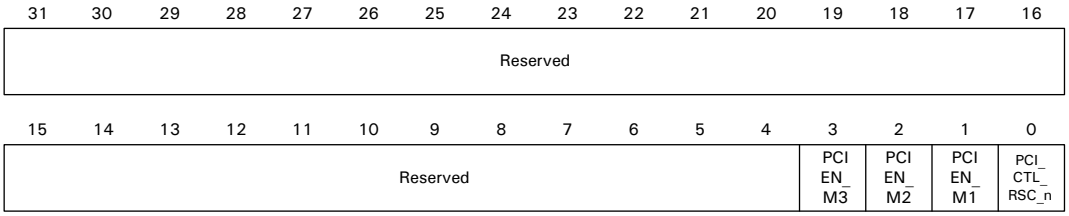
Address Offset	Register	Description
0xA030 0030	PINTEN	PCI Bridge Interrupt Enable
0xA030 0034	PALTMEM0	PCI Bridge AHB to PCI Memory Address Translate 0
0xA030 0038	PALTMEM1	PCI Bridge AHB to PCI Memory Address Translate 1
0xA030 003C	PALTIO	PCI Bridge AHB to PCI IO Address Translate
0xA030 0040	PMALT0	PCI Bridge PCI to AHB Memory Address Translate 0
0xA030 0044	PMALT1	PCI Bridge PCI to AHB Memory Address Translate 1
0xA030 0048	PALTCTL	PCI Bridge Address Translation Control
0xA030 004C	CMISC	CardBus Miscellaneous Support
0xA030 004C–0xA030 0FFC		Reserved (all read accesses return 0x0 value)
0xA030 1000	CSKTEV	CardBus Socket Event
0xA030 1004	CSKTMSK	CardBus Socket Mask
0xA030 1008	CSKTPST	CardBus Socket Present State
0xA030 100C	CSKTFEV	CardBus Socket Force Event
0xA030 1010	CSKTCTL	CardBus Socket Control
0xA030 1014–0xA030 1FFC		Reserved (all read accesses return 0x0 value)

Table 265: PCI arbiter register map

PCI Arbiter Configuration register

Address: A030 0000

The PCI Arbiter Configuration register enables and disables each of the three external PCI bus masters. The internal PCI-to-AHB bridge is always enabled.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:04	Read only; hard-wired to 0	Reserved	N/A	N/A
D03	R/W	PCIEN_M3	0	**External master 3 enable** 0 Disable (default) 1 Enable If the master becomes broken, toggle low -> high to re-enable.
D02	R/W	PCIEN_M2	0	**External master 2 enable** 0 Disable (default) 1 Enable If the master becomes broken, toggle low -> high to re-enable.
D01	R/W	PCIEN_M1	0	**External Master 1 Enable** 0 Disable (default) 1 Enable If the master becomes broken, toggle low-> high to re-enable.

Table 266: PCI Arbiter Configuration register

Bits	Access	Mnemonic	Reset	Description
D00	R	PCI_CTL_RSC_n	N/A	**PCI_CENTRAL_RSC_n input to NS9775** (NS9775 has internal pulldown) 0 NS9775 provides PCI central resource functions (pulldown) 1 NS9775 does not provide PCI central resource functions

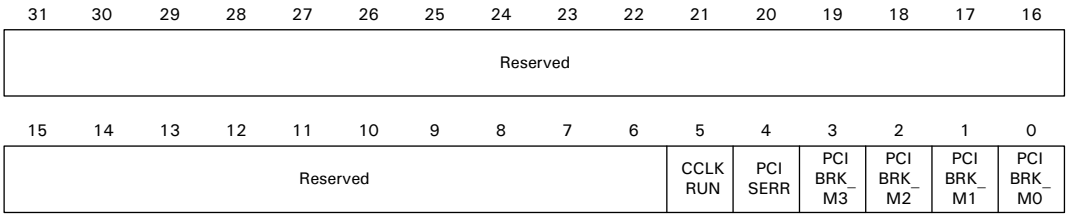
Table 266: PCI Arbiter Configuration register

PCI Arbiter Interrupt Status register

Address: A030 0004

The PCI Arbiter Interrupt Status register reports broken masters (that is, masters that do not respond in 16 clocks after being granted the bus) and PCI system errors from external PCI agents (that is, SERR# asserted for 1 clock cycle). There is a separate bit for each of the interrupt sources, and each bit can cause an interrupt if the associated bit in the PCI Arbiter Interrupt Enable register is set to 1.

Note: For diagnostics, software can cause an interrupt by writing a 1 to a bit that is set to 0. Otherwise, in normal operation, the software writes a 1 to a bit that is set to clear the bit and the interrupt from the PCI arbiter.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:06	Read only; hard-wired to 0	Reserved	N/A	N/A

Table 267: PCI Arbiter Interrupt Status register

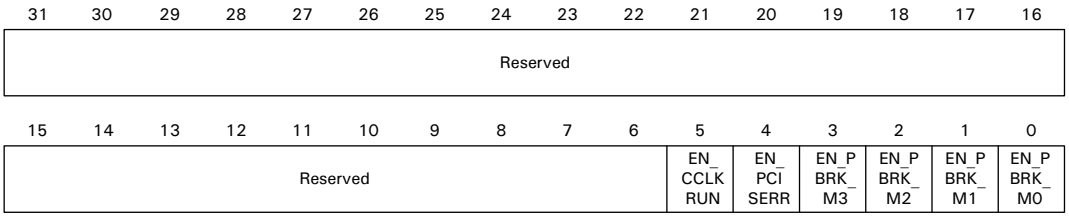
Bits	Access	Mnemonic	Reset	Description
D05	R/C	CCLKRUN	0	**Restart CardBus clock** Used for CardBus Applications only. Indicates that an external CardBus card has asserted CardBus CCLKRUN# to request that the CardBus clock be restarted.
D04	R/C	PCISERR	0	An SERR signal has been received from an external PCI agent.
D03	R/C	PCIBRK_M3	0	External master 3 broken
D02	R/C	PCIBRK_M2	0	External master 2 broken
D01	R/C	PCIBRK_M1	0	External master 1 broken
D00	R/C	PCIBRK_M0	0	PCI-to-AHB bridge broken

Table 267: PCI Arbiter Interrupt Status register

PCI Arbiter Interrupt Enable register

Address: A030 0008

The PCI Arbiter Interrupt Enable register has an enable bit for each of the interrupt status bits in the PCI Arbiter Interrupt Status register. Set these bits to 1 to allow the associated interrupt status bit to cause an interrupt to the system.



Register bit assignment

Blts	Access	Mnemonic	Reset	Description
D31:06	Read only; hard-wired to 0	Reserved	N/A	N/A

Table 268: PCI Arbiter Interrupt Enable register

Bits	Access	Mnemonic	Reset	Description
D05	R/W	EN_CCLKRUN	0	**Enable CCLKRUN# interrupt** 0 Disable (default) 1 Enable
D04	R/W	EN_PCISERR	0	**Enable SERR received from external PCI agent** 0 Disable (default) 1 Enable
D03	R/W	EN_PBRK_M3	0	**Enable external master 3 broken** 0 Disable (default) 1 Enable
D02	R/W	EN_PBRK_M2	0	**Enable external master 2 broken** 0 Disable (default) 1 Enable
D01	R/W	EN_PBRK_M1	0	**Enable external master 1 broken** 0 Disable (default) 1 Enable
D00	R/W	EN_PBRK_M0	0	**Enable PCI-to-AHB bridge broken** 0 Disable (default) 1 Enable

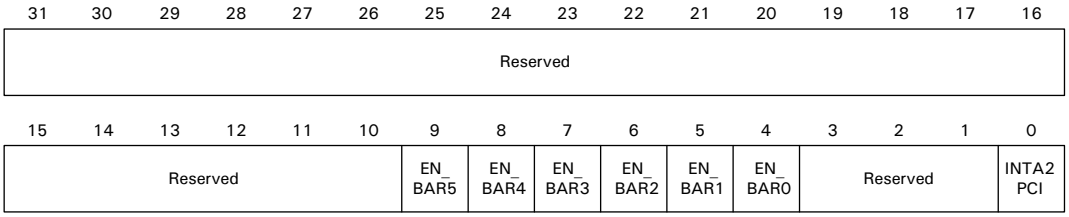
Table 268: PCI Arbiter Interrupt Enable register

PCI Miscellaneous Support register

Address: A030 000C

The PCI Miscellaneous Support register contains miscellaneous PCI functions that are required in NS9775.

- Change the EN_BARx fields only during system initialization, when there is no PCI activity.
- In a system where NS9775 is not the host, the EN_BARx fields must be programmed within 2^{25} PCI clocks of RST# being negated. This is the time allowed from RST# negated to the first configuration cycle on the PCI bus.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:10	Read only; hard-wired to 0	Reserved	N/A	N/A
D09	R/W	EN_BAR5	0	**Enable bridge PCI Base Address register 5** 0 Disable (default) 1 Enable **Note:** Although BAR_x can still be accessed when EN_BAR5 is 1, the address range defined by BAR_x will not be decoded.
D08	R/W	EN_BAR4	0	**Enable bridge PCI Base Address register 4** 0 Disable (default) 1 Enable **Note:** Although BAR_x can still be accessed when EN_BAR4 is 1, the address range defined by BAR_x will not be decoded.
D07	R/W	EN_BAR3	0	**Enable bridge PCI Base Address register 3** 0 Disable (default) 1 Enable **Note:** Although BAR_x can still be accessed when EN_BAR3 is 1, the address range defined by BAR_x will not be decoded.

Table 269: PCI Miscellaneous Support register

Bits	Access	Mnemonic	Reset	Description
D06	R//W	EN_BAR2	0	**Enable bridge PCI Base Address register 2** 0 Disable (default) 1 Enable **Note:** Although BAR_x can still be accessed when EN_BAR2 is 1, the address range defined by BAR_x will not be decoded.
D05	R/W	EN_BAR1	0	**Enable bridge PCI Base Address register 1** 0 Disable (default) 1 Enable **Note:** Although BAR_x can still be accessed when EN_BAR1 is 1, the address range defined by BAR_x will not be decoded.
D04	R/W	EN_BAR0	0	**Enable bridge PCI Base Address register 0** 0 Disable (default) 1 Enable **Note:** Although BAR_x can still be accessed when EN_BAR0 is 1, the address range defined by BAR_x will not be decoded.
D03:01	Read only; hard-wired to 0	Reserved	N/A	N/A
D00	R/W	INTA2PCI	0	The inverted value of this bit drives the INTA# output pin. INTA# is configured as a pseudo-open drain output. 0 INTA# high impedance (default) INTA# must be in high impedance state for CardBus applications and for PCI applications when NS9775 is the host, and provides the interrupt controller for PCI interrupts. 1 Assert INTA# low

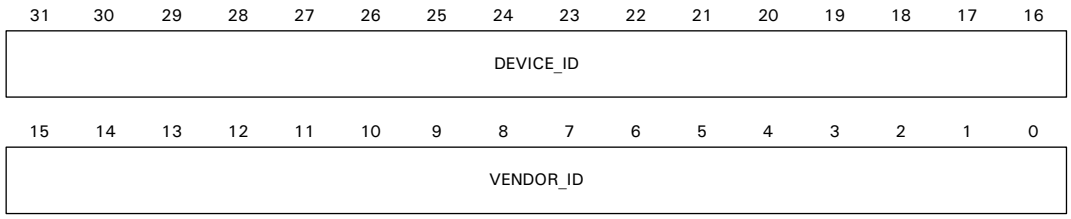
Table 269: PCI Miscellaneous Support register

PCI Configuration 0 register

Address: A030 0010

The PCI Configuration 0 register contains the values that will be read from the PCI Device ID and PCI Vendor ID registers.

Change these fields only during system initialization, when there is no PCI activity. In a system where NS9775 is not the host, these fields must be programmed within 2^{25} PCI clocks of RST# being negated. This is the time allowed from RST# negated to the first configuration cycle on the PCI bus.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:16	R/W	DEVICE_ID	0x00C4	**Device ID value** Value to be inserted into the PCI Device ID register. Defaults to the assigned device ID (0x00C4).
D15:00	R/W	VENDOR_ID	0x114F	**Vendor ID value** Value to be inserted into the PCI Vendor ID register. Defaults to the assigned vendor ID (0x114F).

Table 270: PCI Configuration 0 register

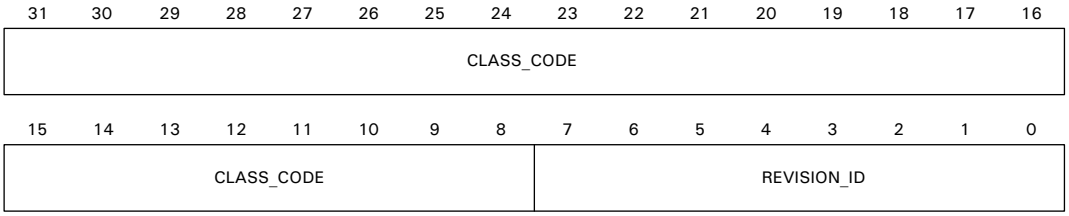
PCI Configuration 1 register

Address: A030 0014

The PCI Configuration 1 register contains the values that will be read from the PCI Class Code and PCI Revision ID registers.

Change these fields only during system initialization, when there is no PCI activity. In a system where NS9775 is not the host, these fields must be programmed within 2^{25}

PCI clocks of RST# being negated. This is the time allowed from RST# negated to the first configuration cycle on the PCI bus.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:08	R/W	CLASS_CODE	0x060000	**Class code value** Value to be inserted into PCI Class Code register. Defaults to class code for a host/PCI bridge (0x060000).
D07:00	R/W	REVISION_ID	0x00	**Revision ID value** Value to be inserted into the PCI Revision ID register. Defaults to 0x00.

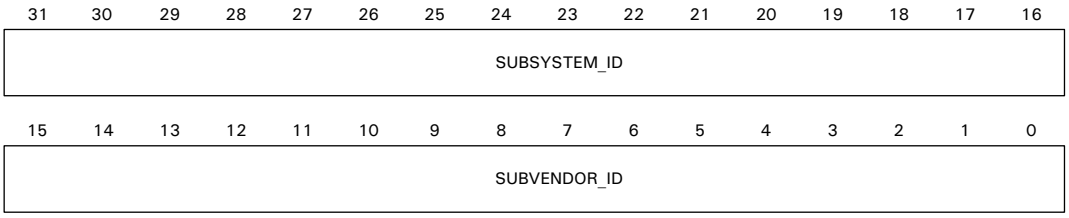
Table 271: PCI Configuration 1 register

PCI Configuration 2 register

Address: A030 0018

The PCI Configuration 2 register contains the values that will be read from the PCI Subsystem ID and PCI Subsystem Vendor ID registers.

Change these fields only during system initialization, when there is no PCI activity. In a system where NS9775 is not the host, these fields must be programmed within 2^{25} PCI clocks of RST# being negated. This is the time allowed from RST# negated to the first configuration cycle on the PCI bus.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:16	R/W	SUBSYSTEM_ID	0x0000	**Subsystem ID value** Value to be inserted into the PCI Subsystem ID register. Defaults to 0x0000.
D15:00	R/W	SUBVENDOR_ID	0x0000	**Subvendor ID value** Value to be inserted into the PCI Subvendor ID register. Defaults to 0x0000.

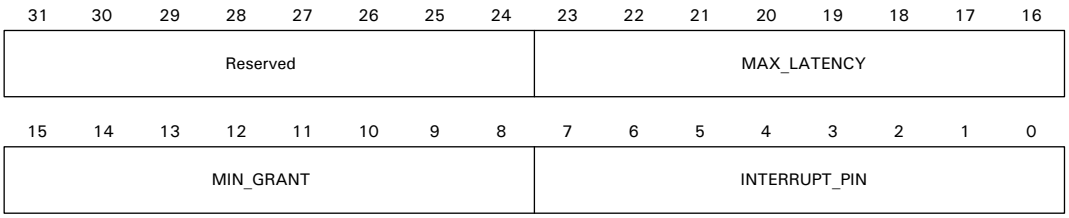
Table 272: PCI Configuration 2 register

PCI Configuration 3 register

Address: A030 001C

The PCI Configuration 3 register contains the values that will be read from the PCI Max_Lat, PCI Min_Gnt, and PCI Interrupt Pin registers.

Change these fields only during system initialization, when there is no PCI activity. In a system where NS9775 is not the host, these fields must be programmed within 2^{25} PCI clocks of RST# being negated. This is the time allowed from RST# negated to the first configuration cycle on the PCI bus.



Register bit assignment

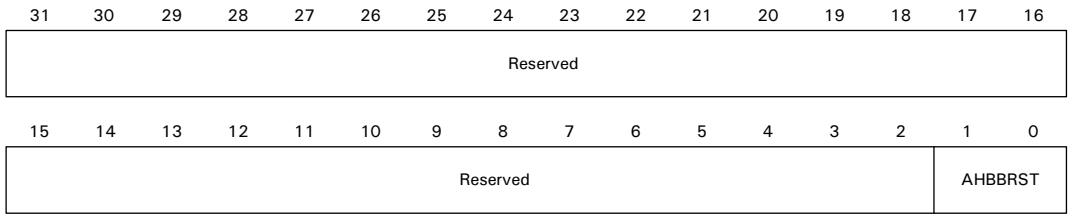
Bits	Access	Mnemonic	Reset	Description
D31:24	Read only; hard-wired to 0	Reserved	N/A	N/A
D23:16	R/W	MAX_LATENCY	0x00	**Max latency value** Value to be inserted into the PCI Max_Lat register. Defaults to 0x00.
D15:08	R/W	MIN_GRANT	0x00	**Min grant value** Value to be inserted into the PCI Min_Gnt register. Defaults to 0x00.
D07:00	R/W	INTERRUPT_PIN	0x01	**Interrupt pin value** Value to be inserted onto the PCI Interrupt Pin register. Defaults to 0x01, which is the encoding for INTA#.

Table 273: PCI Configuration 3 register

PCI Bridge Configuration register

Address: A030 0020

The PCI Bridge Configuration register controls the bandwidth allocated to the bridge. Change the AHBBRST field only during system initialization, when there is no traffic to or from the bridge. Because the setting of this register affects NS9775's bandwidth allocation, changes will have an effect on system performance.



Register bit assignment

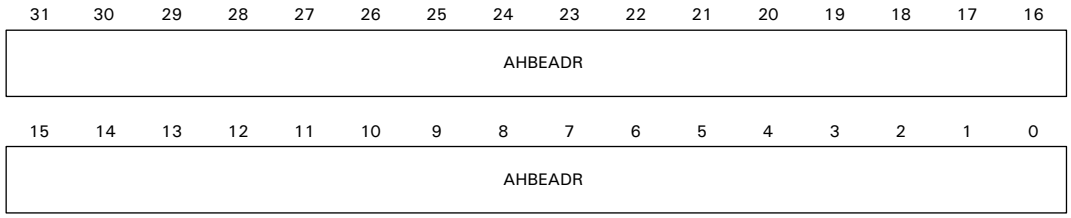
Bits	Access	Mnemonic	Reset	Description
D31:02	Hardwired to 0	Reserved	N/A	N/A
D01:00	R/W	AHBBRST	0x1	**AHB burst length control** Determines the type of burst cycles done when the bridge acts as AHB master: 00 16 01 32 (default) 10 64 11 Reserved

Table 274: PCI Bridge Configuration register

PCI Bridge AHB Error Address register

Address: A030 0024

The PCI Bridge AHB Error Address register stores the address of the AHB transaction that received an AHB ERROR response.



Register bit assignment

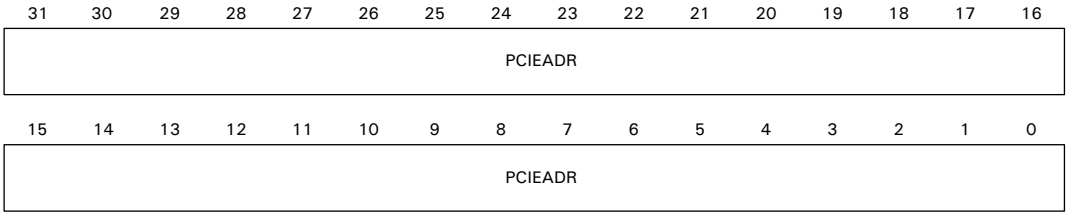
Bits	Access	Mnemonic	Reset	Description
D31:00	R	AHBEADR	0x00000000	**AHB error address** Holds the AHB address that caused the error, when AHBERR is set in the PCI Bridge Interrupt Status register. No further updates are allowed to this register until AHBERR is cleared,

Table 275: PCI Bridge AHB Error Address register

PCI Bridge PCI Error Address register

Address: A030 0028

The PCI Bridge PCI Error Address register stores the address of the PCI transaction that received a PCI bus error response.



Register bit assignment

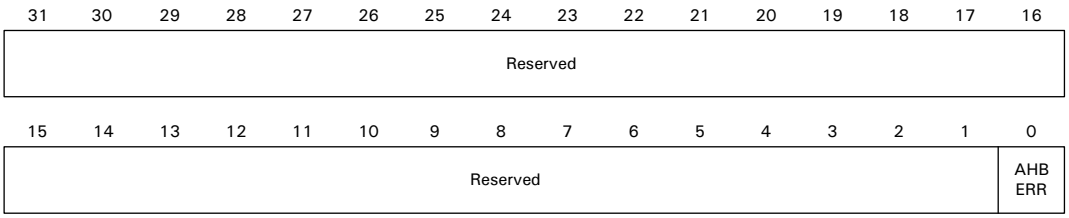
Bits	Access	Mnemonic	Reset	Description
D31:00	R	PCIEADR	0x00000000	**PCI error address** Holds the PCI address that caused an error, when any of the PCI error bits are set in the PCI Status register. No further updates are allowed to this register until all error bits are cleared.

Table 276: PCI Bridge PCI Error Address register

PCI Bridge Interrupt Status register

Address: A030 002C

The PCI Bridge Interrupt Status register shows the status of the AHB bus error interrupt.



Register bit assignment

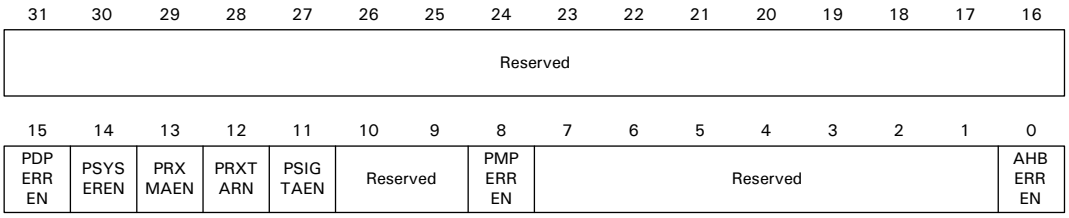
Bits	Access	Mnemonic	Reset	Description
D31:01	Hardwired to 0	Reserved	N/A	N/A
D00	R/C	AHBERR	0	AHB bus error

Table 277: PCI Bridge Interrupt Status register

PCI Bridge Interrupt Enable register

Address: A030 0030

The PCI Bridge Interrupt Enable register stores the enables for all interrupt sources.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:16	Hardwired to 0	Reserved	N/A	N/A
D15	R/W	PDPERREN	0	**PCI detected parity error enable** 0 Interrupt disabled 1 Interrupt enabled Bit 15 of PCI Status register
D14	R/W	PSYSEREN	0	**PCI signaled system error enable** 0 Interrupt disabled 1 Interrupt enabled Bit 14 of PCI Status register

Table 278: PCI Bridge Interrupt Enable register

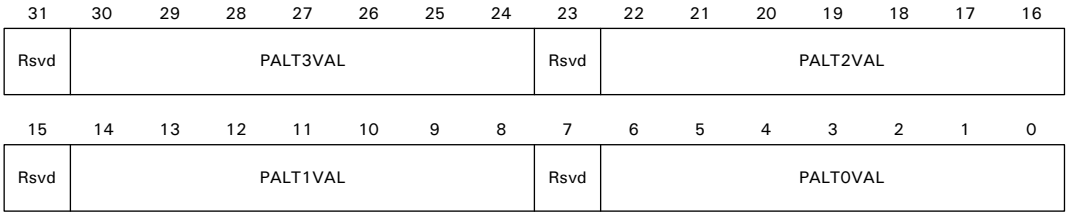
Bits	Access	Mnemonic	Reset	Description
D13	R/W	PRXMAEN	0	**PCI received master abort enable** 0 Interrupt disabled 1 Interrupt enabled Bit 13 of PCI Status register
D12	R/W	PRXTARN	0	**PCI received target abort enable** 0 Interrupt disabled 1 Interrupt enabled Bit 12 of PCI Status register
D11	R/W	PSIGTAEN	0	**PCI signaled target abort enable** 0 Interrupt disabled 1 Interrupt enabled Bit 11 of PCI Status register
D10:09	Hardwired to 0	Reserved	N/A	N/A
D08	R/W	PMPERREN	0	**PCI master data parity error enable** 0 Interrupt disabled 1 Interrupt enabled Bit 8 of PCI Status register
D07:01	Hardwired to 0	Reserved	N/A	N/A
D00	R/W	AHBERREN	0	**AHB bus error enable** 0 Interrupt disabled 1 Interrupt enabled Bit 0 of PCI Bridge Interrupt Status register

Table 278: PCI Bridge Interrupt Enable register

PCI Bridge AHB to PCI Memory Address Translate 0 register

Address: A030 0034

The PCI Bridge AHB-to-PCI Memory Address Translate 0 register translates the AHB addresses sent to the PCI-to-AHB bridge to the appropriate PCI memory addresses.



Register bit assignment

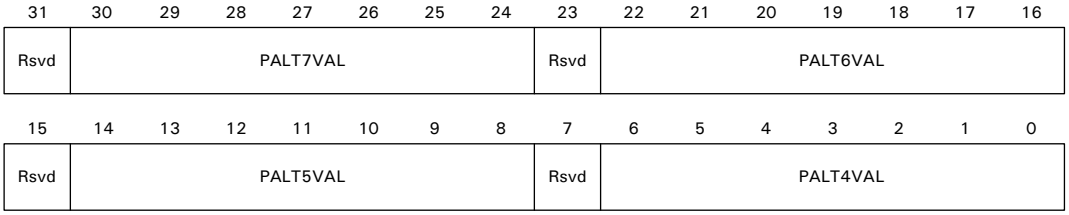
Bits	Access	Mnemonic	Reset	Description
D31	Hardwired to 0	Reserved	N/A	N/A
D30:24	R/W	PALT3VAL	0x00	Bits [31:25] of PCI address when AHB address [27:25] = 011.
D23	Hardwired to 0	Reserved	N/A	N/A
D22:16	R/W	PALT2VAL	0x00	Bits [31:25] of PCI address when AHB address [27:25] = 010.
D15	Hardwired to 0	Reserved	N/A	N/A
D14:08	R/W	PALT1VAL	0x00	Bits [31:25] of PCI address when AHB address [27:25] = 001.
D07	Hardwired to 0	Reserved	N/A	N/A
D06:00	R/W	PALT0VAL	0x00	Bits [31:25] of PCI address when AHB address [27:25] - 000.

Table 279: PCI Bridge AHB-to-PCI Memory Address Translate 0 register

PCI Bridge AHB to PCI Memory Address Translate 1 register

Address: A030 0038

The PCI Bridge AHB-to-PCI Memory Address Translate 1 register translates the AHB addresses sent to the PCI-to-AHB bridge to the appropriate PCI memory addresses.



Register bit assignment

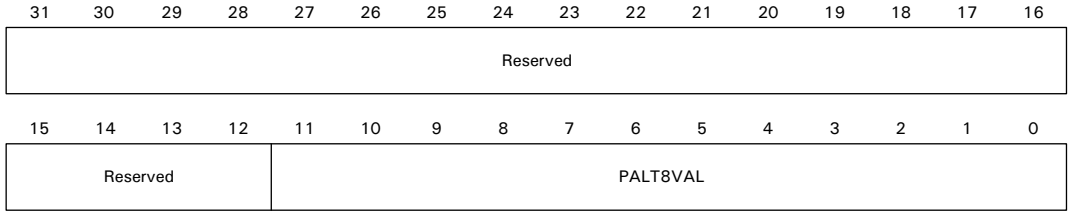
Bits	Access	Mnemonic	Reset	Description
D31	Hardwired to 0	Reserved	N/A	N/A
D30:24	R/W	PALT7VAL	0x00	Bits [31:25] of PCI address when AHB address [27:25] = 111.
D23	Hardwired to 0	Reserved	N/A	N/A
D22:16	R/W	PALT6VAL	0x00	Bits [31:25] of PCI address when AHB address [27:25] = 110.
D15	Hardwired to 0	Reserved	N/A	N/A
D14:08	R/W	PALT5VAL	0x00	Bits [31:25] of PCI address when AHB address [27:25] = 101.
D07	Hardwired to 0	Reserved	N/A	N/A
D06:00	R/W	PALT4VAL	0x00	Bits [31:25] of PCI address when AHB address [27:25] = 100.

Table 280: PCI Bridge AHB-to-PCI Memory Address Translate 1 register

PCI Bridge AHB-to-PCI IO Address Translate register

Address: A030 003C

The PCI Bridge AHB-to-PCI IO Address Translate register translates the AHB addresses sent to the PCI-to-AHB bridge to the appropriate PCI IO addresses.



Register bit assignment

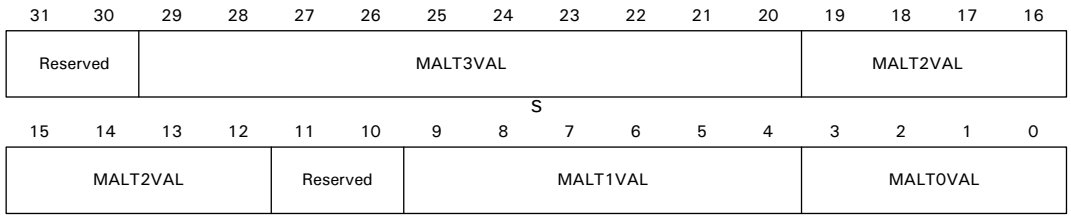
Bits	Access	Mnemonic	Reset	Description
D31:12	Hardwired to 0	Reserved	N/A	N/A
D11:00	R/W	PALT8VAL	0x000	Bits [31:20] of PCI IO address when AHB addresses PCI IO space.

Table 281: PCI Bridge AHB-to-PCI IO Address Translate register

PCI Bridge PCI to AHB Memory Address Translate 0

Address: A030 0040

The PCI Bridge PCI-to-AHB Memory Address Translate 0 register translates the PCI memory addresses to the appropriate AHB memory addresses.



Register bit assignment

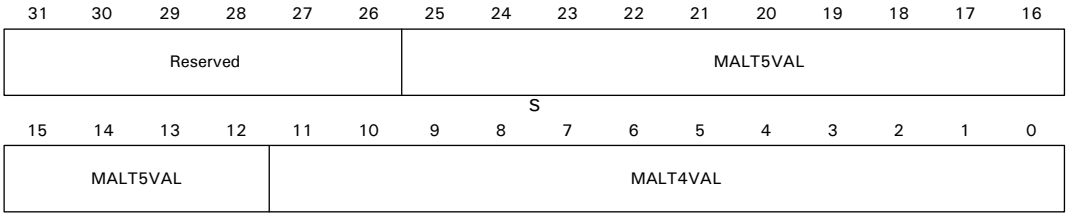
Bits	Access	Mnemonic	Reset	Description
D31:30	Hardwired to 0	Reserved	N/A	N/A
D29:20	R/W	MALT3VAL	0x000	Bits [31:22] of AHB address if PCI address matches BAR3.
D19:12	R/W	MALT2VAL	0x00	Bits [31:24] of AHB address if PCI address matches BAR2.
D11:10	Hardwired to 0	Reserved	N/A	N/A
D09:04	R/W	MALT1VAL	0x00	Bits [31:26] of AHB address if PCI address matches on BAR1.
D03:00	R/W	MALT0VAL	0x0	Bits [31:28] of AHB address if PCI address matches BAR0.

Table 282: PCI Bridge PCI-to-AHB Memory Address Translate 0 register

PCI Bridge PCI to AHB Memory Address Translate 1

Address: A030 0044

The PCI Bridge PCI-to-AHB Memory Translate 1 register translates the PCI memory addresses to the appropriate AHB memory addresses.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:26	Hardwired to 0	Reserved	N/A	N/A

Table 283: PCI Bridge PCI-to-AHB Memory Address Translate 1 register

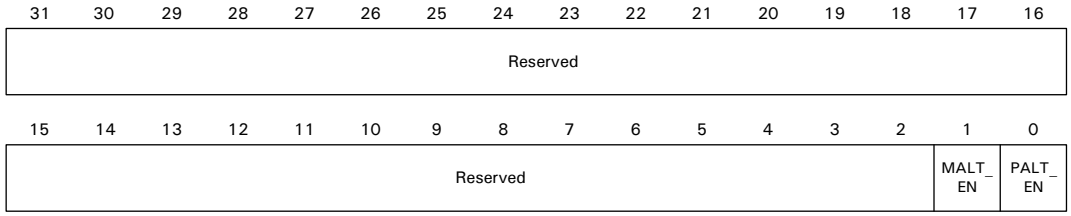
Bits	Access	Mnemonic	Reset	Description
D25:12	R/W	MALT5VAL	0x0000	Bits [31:18] of AHB address if PCI address matches BAR5.
D11:00	R/W	MALT4VAL	0x000	Bits [31:20] of AHB address if PCI address matches BAR4.

Table 283: PCI Bridge PCI-to-AHB Memory Address Translate 1 register

PCI Bridge Address Translation Control register

Address: A030 0048

The PCI Bridge Address Translation Control register controls the address translation process in both direction (AHB-to-PCI and PCI-to-AHB).



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:02	Hardwired to 0	Reserved	N/A	N/A
D01	R/W	MALT_EN	0	**Enable PCI to AHB address translation** 0 Do not translate PCI addresses. The same addresses are used for both PCI and AHB. 1 Translate PCI addresses per the MALTxxVAL fields in the PCI Bridge PCI-to-AHB Memory Address Translate registers (see page 451 and page 452).

Table 284: PCI Bridge Address Translation Control register

Bits	Access	Mnemonic	Reset	Description
D00	R/W	PALT_EN	0	**Enable AHB-to-PCI address translation for both PCI memory and IO space** 0 Do not translate AHB addresses. The same addresses are used for both PCI and AHB. 1 Translate AHB addresses per the PALTxxVAL fields in the PCI Bridge AHB-to-PCI Memory Address Translate registers (see page 449 and page 450) and the PCI Bridge AHB-to-PCI IO Address Translate register (see page 451).

Table 284: PCI Bridge Address Translation Control register

CardBus Miscellaneous Support register

Address: A030 004C

The CardBus Miscellaneous Support register is used for CardBus applications only, and provides NS9775-specific CardBus control and status. (See the *NS9775 Sample Driver Configurations* for examples of how this register is used.)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
CMS_YV_SKT	CMS_XV_SKT	CMS_V3 SKT	CMS_V5 SKT	Rsvd	CMS_YV_CARD	CMS_XV CARD	CMS_V3_CARD	CMS_V5 CARD	CMS_BAD_VCC	CMS_DATA_LOST	CMS_NOTA_CARD	CMS_CB_CARD	CMS_CARD_16	CMS_PWR_CYC	CMS_CCD2

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CMS_CCD1	Reserved				REQ_INTGT_EN	REQ_INT GATE	INTER-RO-GATE	Rsvd	CCLK RUN_EN	CVS2	CVS1	CCLK_STOP_NACK	CCLK_STOP_ACK	CCD2	CCD1

Register Bit Assignment

Bits	Access	Mnemonic	Reset	Description
D31	R/W	CMS_YV_SKT	0	Allows software to control the YV_SKT bit in the CardBus Socket Present State register. When set, indicates that VCC=Y.Y volts can be supplied to the socket.

Table 285: CardBus Miscellaneous Support register

Bits	Access	Mnemonic	Reset	Description
D30	R/W	CMS_XV_SKT	0	Allows software to control the XV_SKT bit in the CardBus Socket Present State register. When set, indicates that VCC=X.X volts can be supplied to the socket.
D29	R/W	CMS_V3_SKT	0	Allows software to control the V3_SKT bit in the CardBus Socket Present State register. When set, indicates that VCC=3.3 volts can be supplied to the socket.
D28	R/W	CMS_V5_SKT	0	Allows software to control the V5_SKT bit in the CardBus Socket Present State register. When set, indicates that VCC=5 volts can be supplied to the socket.
D27	Hard-wired to 0	Reserved	N/A	N/A
D26	R/W	CMS_YV_CARD	0	Allows software to control the YV_CARD bit in the CardBus Socket Present State register. When set, indicates that the card inserted into the socket supports VCC=Y.Y volts.
D25	R/W	CMS_XV_CARD	0	Allows software to control the XV_CARD bit in the CardBus Socket Present State register. When set, indicates that the card inserted into the socket supports VCC=X.X volts.
D24	R/W	CMS_V3_CARD	0	Allows the software to control the V3-CARD bit in the CardBus Socket Present State register. When set, indicates that the card inserted into the socket supports VCC=3.3 volts.

Table 285: CardBus Miscellaneous Support register

Bits	Access	Mnemonic	Reset	Description
D23	R/W	CMS_V5_CARD	0	Allows software to control the V5_CARD bit in the CardBus Socket Present State register. When set, indicates that the card inserted into the socket supports VCC=5 volts.
D22	R/W	CMS_BAD_VCC_REQ	0	Allows software to control the BAD_VCC_REQ bit in the CardBus Socket Present State register. When set, indicates that there was an attempt to apply an unsupported or incorrect voltage to the socket.
D21	R/W	CMS_DATA_LOST	0	Allows software to control the DATA_LOST bit in the CardBus Socket Present State register. When set, indicates that the external card was removed from the socket while the interface was active, and data may have been lost.
D20	R/W	CMS_NOTA_CARD	0	Allows the software to control the NOTA_CARD bit in the CardBus Socket Present State register. When set, indicates that an unsupported card is inserted in the socket.
D19	R/W	CMS_CB_CARD	0	Allows software to control the CB_CARD bit in the CardBus Socket Present State register. When set, indicates that a CardBus card is inserted in the socket.
D18	R/W	CMS_CARD_16	0	Allows software to control the CARD_16 bit in the CardBus Socket Present State register. When set, indicates that a 16-bit PC card is inserted in the socket.

Table 285: CardBus Miscellaneous Support register

Bits	Access	Mnemonic	Reset	Description
D17	R/W	CMS_PWR_CYC	0	Allows software to control the PWR_CYC bit in the CardBus Socket Present State register. When set, indicates that the socket is powered up. When cleared, indicates that the socket is powered down.
D16	R/W	CMS_CCD2	0	Allows software to control the CCD2 bit in the CardBus Socket Present State register. Reflects the current state of the CardBus CCD#2 pin: 0 A card is inserted in the socket. 1 No card is in the socket. Because CCD2 can be shorted to either CVS2 or CVS1, the value here applies when CVS[2:1] are both 0.
D15	R/W	CMS_CCD1	0	Allows the software to control the CCD1 bit in the Cardbus Socket Present State register. Reflects the current state of the CardBus CCD#1 pin: 0 A card is inserted in the socket. 1 No card is in the socket. Because CCD#1 can be shorted to either CVS2 or CVS1, the value here applies when CVS[2:1] are both 0.
D14:11	Hard-wired to 0	Reserved	N/A	N/A
D10	R/W	REQ_INTGT_EN	0	**Enable for REQ_INTGATE interrupt** 0 Disable interrupt (default) 1 Enable interrupt

Table 285: CardBus Miscellaneous Support register

Bits	Access	Mnemonic	Reset	Description
D09	R/C	REQ_INTGATE	0	**CardBus interrogate socket request** Set to 1 when a 1 is written to the CV_TEST bit in the CardBus Force Event register. This bit causes an interrupt to the CPU when the REQ_INTGT_EN bit (D10 in this register) is set.
D08	R/W	INTERROGATE	0	**Socket interrogation** 0 Socket interrogation not in process 1 Socket interrogation on process Set to 1 during socket interrogation, to prevent changes in CCD#1, CCD#2, and CSTSCHG# from affecting the values in the CardBus Socket Event register.
D07	Hard-wired to 0	Reserved	N/A	N/A
D06	R/W	CCLKRUN_EN	0	**CardBus CCLKRUN# enable** 0 Attempt to negate CardBus CCLKRUN# using CCLKRUN# protocol 1 Assert CardBus CCLKRUN#
D05	R/W	CVS2	0	Value driven out on CVS2 pin during socket interrogation.
D04	R/W	CVS1	0	Value driven out on CVS1 pin during socket interrogation.
D03	R	CCLK_STOP_NACK	0	**Response to request to negate CardBus CCLKRUN# using CCLKRUN# protocol** 0 CCLKRUN# request not refused yet. Check CCLK_STOP_ACK to determine whether CCLKRUN# is negated. 1 CCLKRUN# not negated because the external CardBus device will not allow it.

Table 285: CardBus Miscellaneous Support register

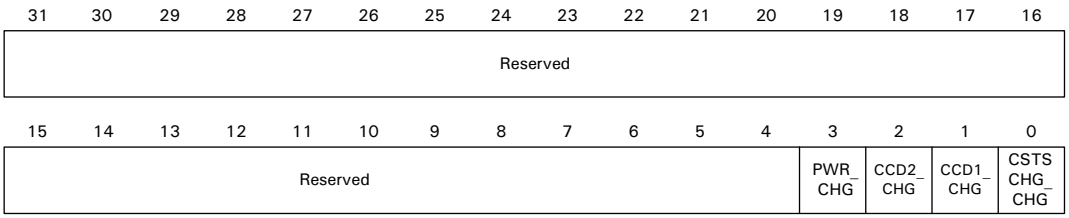
Bits	Access	Mnemonic	Reset	Description
D02	R	CCLK_STOP_ACK	0	**Response to request to negate CardBus CCLKRUN# using CCLKRUN# protocol** 0 CCLKRUN# not negated yet. Check CCLK_STOP_NACK to determine whether CCLKRUN# is not negated because the external CardBus device will not allow it. 1 CCLKRUN# successfully negated
D01	R	CCD2	0	Current state of CCD2 pin.
D00	R	CCD1	0	Current state of CCD1 pin.

Table 285: CardBus Miscellaneous Support register

CardBus Socket Event register

Address: A030 1000

The CardBus Socket Event register is used for CardBus applications only, and indicates a change in socket status.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:04	Hardwired to 0	Reserved	N/A	N/A
D03	R/C	PWR_CHG	0	Set when the PWR_CYC bit in the CardBus Socket Present State register changes. This bit can also be set by writing a 1 to the FPWR_CHG bit in the CardBus Socket Force Event register.

Table 286: CardBus Socket Event register

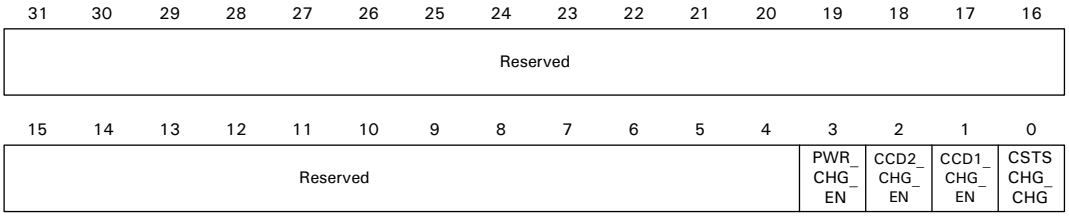
Bits	Access	Mnemonic	Reset	Description
D02	R/C	CCD2_CHG	0	Set when the CCD#2 signal changes. Changes during card interrogation (when the INTERROGATE bit is set to 1 in the CardBus Miscellaneous Support register) are ignored. This bit can also be set by writing a 1 to the FCCD2_CHG bit in the CardBus Socket Force Event register.
D01	R/C	CCD1_CHG	0	Set when the CCD#1 signal changes. Changes during card interrogation (when the INTERROGATE bit is set to 1 in the CardBus Miscellaneous Support register) are ignored. This bit can also be set by writing a 1 to the FCCD1_CHG bit in the CardBus Socket Force Event register.
D00	R/C	CSTSCHG_CHG	0	Set when the CSTSCHG signal changes from low to high. Changes during card interrogation (when the INTERROGATE bit is set to 1 in the CardBus Miscellaneous Support register) are ignored. This bit can also be set by writing a 1 to the FCSTSCHG_CHG bit in the CardBus Socket Force Event register.

Table 286: CardBus Socket Event register

CardBus Socket Mask register

Address: A030 1004

The CardBus Socket Mask register is used for CardBus applications only, and contains the interrupt enable bits for each of the bits in the CardBus Socket Event register.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:04	Hardwired to 0	Reserved	N/A	N/A
D03	R/W	PWR_CHG_EN	0	**Power cycle interrupt enable** 0 Interrupt disabled 1 Interrupt enabled
D02	R/W	CCD2_CHG_EN	0	**CCD2 change interrupt enable** 0 Interrupt disabled 1 Interrupt enabled
D01	R/W	CCD1_CHG_EN	0	**CCD1 change interrupt enable** 0 Interrupt disabled 1 Interrupt enabled
D00	R/W	CSTSCHG_CHG_EN	0	**CSTSCHG change interrupt enable** 0 Interrupt disabled 1 Interrupt enabled

Table 287: CardBus Socket Mask register

CardBus Socket Present State register

Address: A030 1008

The CardBus Socket Present State register is used for CardBus applications only, and contains status information about the CardBus socket.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
YV_SKT	XV_SKT	V3_SKT	V5_SKT	ZV_SUPP	Reserved										

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Reserved		YV_CARD	XV_CARD	V3_CARD	V5_CARD	BAD_VCC_REQ	DATA_LOST	NOTA_CARD	CINT	CB_CARD	CARD_16	PWR_CYC	CCD2	CCD1	CSTSCHG

Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31	R	YV_SKT	0	When set, indicates that VCC=Y.Y volts can be supplied to the socket.
D30	R	XV_SKT	0	When set, indicates that VCC=X.X volts can be supplied to the socket.
D29	R	V3_SKT	0	When set, indicates that VCC=3.3 volts can be supplied to the socket.
D28	R	V5_SKT	0	When set, this bit indicates that VCC=5 volts can be supplied to the socket.
D27	Hard-wired to 0	ZV_SUPPORT	0	**Zoomed video support** Always set to 0, as NS9775 does not support this bit.
D26:14	Hard-wired to 0	Reserved	N/A	N/A
D13	R	YV_CARD	0	When set, indicates that the card inserted into the socket supports VCC=Y.Y volts. This bit can also be set by writing a 1 to the FYV_CARD bit in the CardBus Socket Force Event register.
D12	R	XV_CARD	0	When set, indicates that the card inserted into the socket supports VCC=X.X volts. This bit can also be set by writing a 1 to the FXV_CARD in the CardBus Socket Fore Event register.
D11	R	V3_CARD	0	When set, indicates that the card inserted into the socket supports VCC=3.3 volts. This bit can also be set by writing a 1 to the FV3_CARD bit in the CardBus Socket Force Event register.
D10	R	V5_CARD	0	When set, indicates that the card inserted into the socket supports VCC=5 volts. This bit can also be set by writing a 1 to the FV5_CARD bit in the CardBus Socket Force Event register.

Table 288: Cardbus Socket Present State register

Bits	Access	Mnemonic	Reset	Description
D09	R	BAD_VCC_REQ	0	When set, indicates that the software tried to apply an unsupported or incorrect voltage to the socket. This bit can also be set by writing a 1 to the FBAD_VCC_REQ bit in the CardBus Socket Force Event register.
D08	R	DATA_LOST	0	When set, indicates that the external card was removed from the socket while the interface was active, and data may have been lost. This bit can also be set by writing a 1 to the FDATA_LOST bit in the CardBus Socket Force Event register.
D07	R	NOTA_CARD	0	When set, indicates that an unsupported card is inserted in the socket. This bit can also be set by writing a 1 to the FNOTA_CARD bit in the CardBus Socket Force Event register when a card is not in the socket.
D06	R	CINT	0	**Inverted current state of the CardBus CINT# pin** 0 CINT# negated 1 CINT# asserted
D05	R	CB_CARD	0	When set, indicates that a CardBus card is inserted in the socket. This bit can also be set by writing a 1 to the FCB_CARD bit in the CardBus Socket Force Event register when a card is not inserted in the socket.
D04	R	CARD_16	0	When set, indicates that a 16-bit PC card is inserted in the socket. This bit can also be set by writing a 1 to the FCARD_16 bit in the CardBus Socket Force Event register when a card is not inserted in the socket.

Table 288: Cardbus Socket Present State register

Bits	Access	Mnemonic	Reset	Description
D03	R	PWR_CYC	0	When set, indicates that the socket is powered up. When cleared, this bit indicates that the socket is powered down.
D02	R	CCD2	0	**Current state of the CardBus CCD#2 pin** 0 A card is inserted in the socket. 1 No card is in the socket. Because CCD2 can be shorted to either CVS2 or CVS1, the value here applies when CVS[2:1] are both 0.
D01	R	CCD1	0	**Current state of the CardBus CCD#1 pin** 0 A card is inserted in the socket. 1 No card is in the socket. Because CCD1 can be shorted to either CVS2 or CVS1, the value here applies when CVS[2:1] are both 0.
D00	R	CSTSCHG	0	**Current state of the CardBus CSTSCHG pin** 0 CSTSCHG negated 1 CSTSCHG asserted

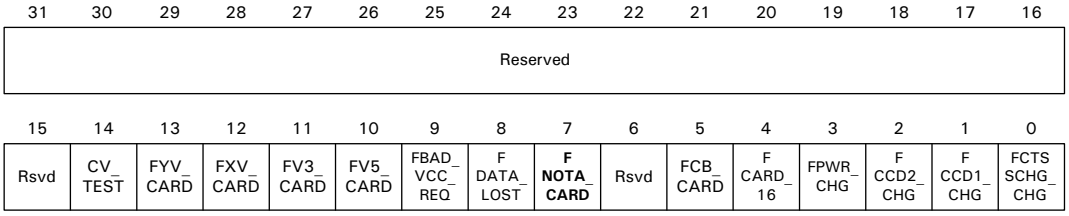
Table 288: Cardbus Socket Present State register

CardBus Socket Force Event register

Address: A030 100C

The CardBus Socket Force Event register is used for CardBus applications only. This register is implemented only as an address that is written to force various status and event bits in the CardBus host bridge through software. Writing a 1 to a bit in this register sets a corresponding bit in the CardBus Socket Event register or CardBus Socket Present State register.

Note: The CardBus Socket Force Event register sets selected bits that are in the CardBus Socket Present State register. Clear these bits by clearing the corresponding bits in the CardBus Miscellaneous Support register.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:15	N/A	Reserved	N/A	N/A
D14	W	CV_TEST	N/A	■ Requests that the card interrogation procedure be run again. ■ Sets the REQ_INGATE bit in the CardBus Miscellaneous Support register to 1. ■ If the REQ_INGATE_EN bit in the CardBus Miscellaneous Support register is set, writing a 1 to this bit causes an interrupt back to the CPU.
D13	W	FYV_CARD	N/A	Sets the YV_CARD bit in the CardBus Socket Present State register.
D12	W	FXV_CARD	N/A	Sets the XV_CARD bit in the CardBus Socket Present State register.
D11	W	FV3_CARD	N/A	Sets the V3_CARD bit in the CardBus Socket Present State register.
D10	W	FV5_CARD	N/A	Sets the V5_CARD bit in the CardBus Socket Present State register.
D09	W	FBAD_VCC_REQ	N/A	Sets the BAD_VCC_REQ bit in the CardBus Socket Present State register.
D08	W	FDATA_LOST	N/A	Sets the DATA_LOST bit in the CardBus Socket Present State register.

Table 289: CardBus Socket Force Event register

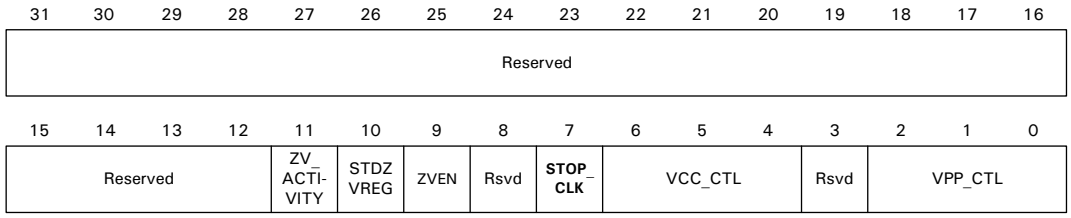
Bits	Access	Mnemonic	Reset	Description
D07	W	FNOTA_CARD	N/A	Sets the NOTA_CARD bit in the CardBus Socket Present State register. If a card is in the socket (that is, CMISC_CCD[1:0] = 00 in the CardBus Miscellaneous Support register), writes to this bit are ignored.
D06	N/A	Reserved	N/A	N/A
D05	W	FCB_CARD	N/A	Sets the CB_CARD bit in the CardBus Socket Present State register. If a card is in the socket (that is, CMISC_CCD[1:0] = 00 in the CardBus Miscellaneous Support register), writes to this bit are ignored.
D04	W	FCARD_16	N/A	Sets the CARD_16 bit in the CardBus Socket Present State register. If a card is in the socket (that is, CMISC_CCD[1:0] = 00 in the CardBus Miscellaneous Support register), writes to this bit are ignored.
D03	W	FPWR_CHG	N/A	Sets the PWR_CHG bit in the CardBus Socket Event register. This does not affect the PWR_CYC bit in the CardBus Socket Present State register.
D02	W	FCCD2_CHG	N/A	Sets the CCD2_CHG bit in the CardBus Socket Event register. This does not affect the CCD2 bit in the CardBus Socket Present State register.
D01	W	FCCD1_CHG	N/A	Sets the CCD1_CHG bit in the CardBus Socket Event register. This does not affect the CCD1 bit in the CardBus Socket Present State register.
D00	W	FCSTSCHG_CHG	N/A	Sets the CSTSCHG_CHG bit in the CardBus Socket Event register, This does not affect the CSTSCHG bit in the CardBus Socket Present State register.

Table 289: CardBus Socket Force Event register

CardBus Socket Control register

Address: A030 1010

The CardBus Socket Control register is used only for CardBus applications.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:12	Hardwired to 0	Reserved	N/A	N/A
D11	Hardwired to 0	ZV_ACTIVITY	0	**Zoomed video activity bit** Hardwired to 0.
D10	Hardwired to 0	STANDARDZVREG	0	**Standardized zoomed video register model support** Hardwired to 0.
D09	R/W	ZVEN	0	**Zoomed video enable** Defaults to 0
D08	Hardwired to 0	Reserved	N/A	N/A
D07	R/W	STOP_CLK	0	**Stop CardBus clock** Defaults to 0.
D06:04	R/W	VCC_CTL	000	**Socket VCC control** 000 0 V 001 Reserved 010 5 V 011 3.3 V 1xx Reserved
D03	Hardwired to 0	Reserved	N/A	N/A

Table 290: CardBus Socket Control register

Bits	Access	Mnemonic	Reset	Description
D02:00	R/W	VPP_CTL	000	**Socket VPP/Core control** 000 0 V 001 12 V 010 5 V 011 3.3 V 100 Reserved 101 Reserved 110 1.8 V 111 Reserved

Table 290: CardBus Socket Control register

PCI system configurations

NS9775 can be connected to the PCI bus using an embedded (internal) or external PCI bus arbiter. Figure 73 shows how NS9775 is connected to the PCI bus for a typical system application using the embedded PCI bus arbiter, and where the NS9775 provides the central resource function (see "PCI central resource functions" on page 472). Up to three external masters are supported.

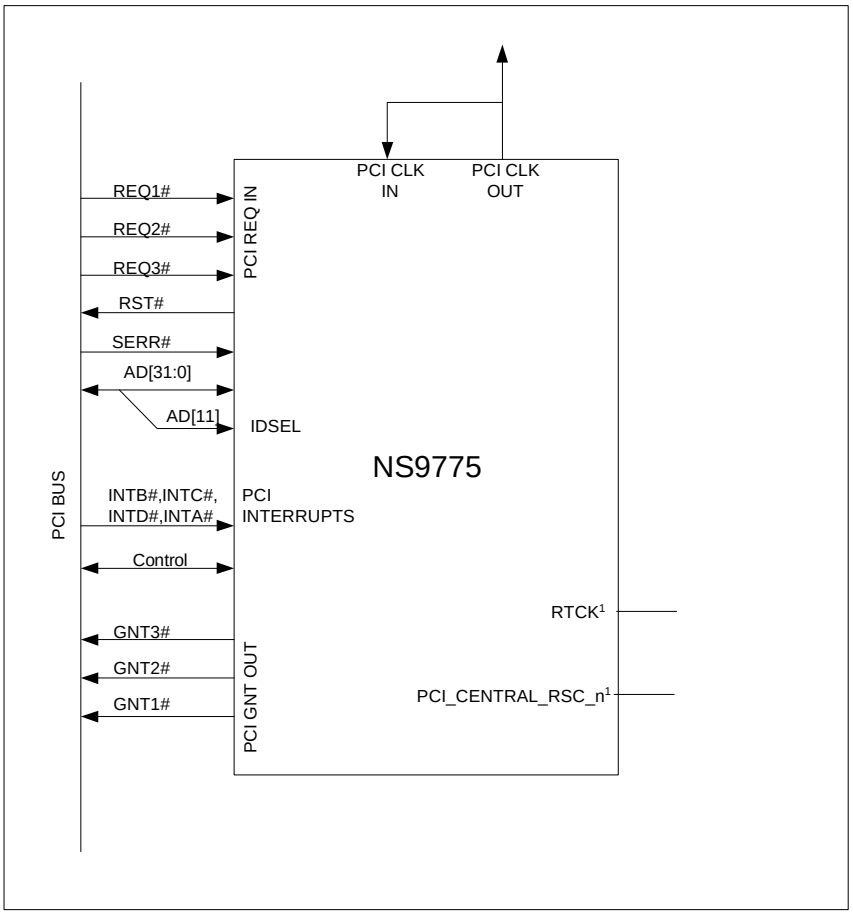


Figure 73: System connections to NS9775 — Internal arbiter and central resources

Note:

1 These pins are not connected because internal resistors tie these pins to the appropriate state.

The internal PCI arbiter is selected when the RTCK pin is set to 1 during powerup. Because the RTCK pad has a weak internal pullup, no external components are required to select the internal PCI arbiter.

Figure 74 shows how NS9775 is connected to the PCI bus for a typical application using an external PCI bus arbiter, and where the NS9775 does not provide the PCI central resource functions (see "PCI central resource functions" on page 472). RTCK is pulled low by an external resistor to configure NS9775 to use an external arbiter. The REQ0#/GNT0# pair for the external PCI arbiter is multiplexed out on the GNT1#/REQ1# pins — GNT1# to REQ0# and REQ1# to GNT0#.

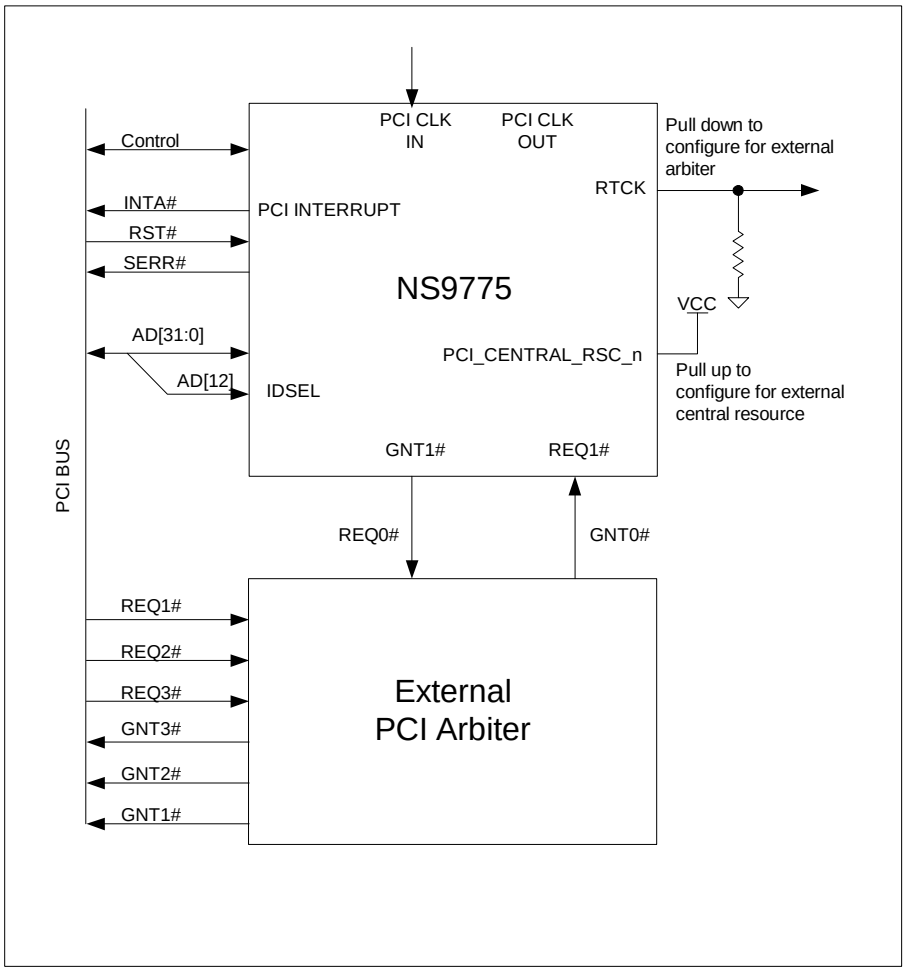


Figure 74: System connections to NS9775 — External arbiter and central resources

Device selection for configuration

The NS9775 IDSEL pin is used as a chip select during PCI configuration transactions. If the bridge's configuration registers are being programmed using the AHB bus, NS9775 must be set as Device 0 (see Figure 73, "System connections to NS9775 — Internal arbiter and central resources," on page 469, which shows IDSEL connected to AD[11] and which configures NS9775 as PCI Device 0).

If the bridge's configuration registers are programmed using an external PCI device, NS9775 can be configured as any PCI device number (see Figure 74, "System connections to NS9775 — External arbiter and central resources," on page 471, which shows IDSEL connected to AD[12] and which configured NS9775 as Device 1). Any accesses from the AHB bus to the bridge's configuration registers, however, must be done as Device 0.

PCI interrupts

NS9775 can serve as the interrupt controller for all four PCI interrupts. These interrupts go directly to the interrupt controller in the System Control module. Because these interrupts are open-drain type signals, the transition from low to high is relatively slow once the source of the interrupt is cleared. SERR# input can also cause an interrupt through PCISERR (in the PCI Arbiter Interrupt Status register).

Important: The system software must provide adequate time for the interrupt signals and SERR# to rise before re-enabling them.

If an external interrupt controller is used, NS9775 can drive INTA# using INTA2PCI (in the PCI Miscellaneous Support register).

PCI central resource functions

NS9775 provides several PCI central resource functions when NS9775's PCI_CENTRAL_RSC_n pin is pulled low (see Figure 73):

- RST# to the PCI system is driven through NS9775. RST# is asserted asynchronously and negated synchronously to the PCI clock. RST# is driven from the system reset to NS9775 and the PCI bit in the Reset and Sleep Control register in the System Control Module.
- SERR# is configured as an input.
- AD[31:0], C/BE[3:0], and PAR are driven low when RST# is asserted, to keep the signals from floating.

When the PCI_CENTRAL_RSC_n pin is pulled high (see Figure 74), these functions operate differently:

- RST# is configured as an input, and must be supplied by the system. In this situation, RST# is used as another system reset to NS9775; that is, either reset_n or RST# can reset NS9775, and both must be negated to take NS9775 out of reset.
- SERR# is configured as output.
- AD[31:0], C/BE[3:0], and PAR are tri-stated when RST# is asserted.

The system must provide pullup resistors on the following signals, regardless of the state of PCI_CENTRAL_RSC_n:

- FRAME#
- TRDY#
- IRDY#
- DEVSEL#
- STOP#
- SERR#
- PERR#
- LOCK#

  Note: The NS9775 does not have a LOCK# pin associated with it. If any PCI device in the system uses the LOCK# signal, the signal must have a pullup resistor.
- INTA#
- INTB#
- INTC#
- INTD#
- All REQ# inputs to NS9775
- All GNT# outputs from NS9775 that are connected to other PCI devices in the system (because they are tri-stated during RST#)

The PCI clock can be either generated from NS9775 (see Figure 73, "System connections to NS9775 — Internal arbiter and central resources," on page 469) or provided by an external source (see Figure 74, "System connections to NS9775 — External arbiter and central resources," on page 471). The PCI CLK input pad has a weak internal pullup.

Important: Note that in cases where NS9775 provides the PCI clock, the PCI clock connection to the NS9775 must still be made external to the NS9775, as shown in Figure 74 (that is, connect `PCI_clk_out` to `PCI_clk_in`). This is done to minimize the clock skew between the NS9775 and external PCI devices.

CardBus Support

NS9775 can support 32-bit CardBus applications using the existing PCI port and existing PCI-to-AHB bridge IP.

Figure 75 shows how NS9775 is configured for CardBus applications. The CardBus model has only one external card connected to a host adapter or PCI-to-CardBus bridge through a socket. All connections are point-to-point, and both the host adapter and the external card can be masters on the bus.

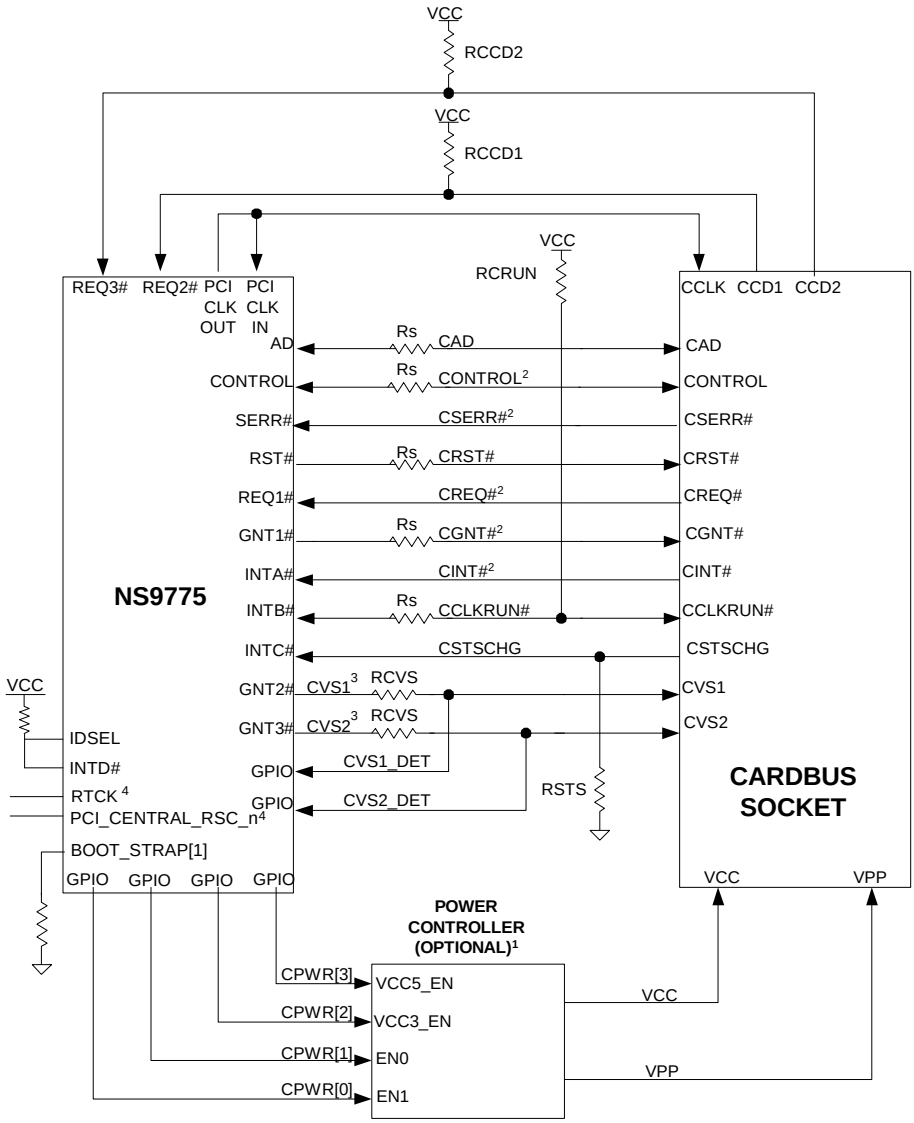


Figure 75: CardBus system connections to NS9775

Notes:

1. The power controller is required only for applications that support hot-insertion and hot-removal of the CardBus card. This requires additional components to isolate NS9775 from CardBus.
2. The system must provide external pullup per PCI specification. CAD, C/BE, and PAR do not require pullups.
3. Voltage detection signal optional for embedded system.
4. Pins not connected because internal resistors tie these to the appropriate state.

Configuring NS9775 for CardBus support

Although many CardBus signals are the same as those for the PCI bus, there are some unique signals. Table 291 lists the new signals and indicates the PCI signals with which they are multiplexed for NS9775.

PCI Signal	CardBus Signal	CardBus type	Comments
INTA#	CINT#	Input	Cardbus interrupt pin. INTA2PCI in the PCI Miscellaneous Support register must be 0.
INTB#	CCLKRUN#	Bidir	CardBus pin used to negotiate with the external CardBus device before stopping the clock. Also allows external CardBus device to request that the clock be restarted.
INTC#	CSTSCHG	Input	CardBus status change interrupt signal.
GNT1#	CGNT#	Output	Grant to external CardBus device from NS9775's internal arbiter.
GNT2#	CVS1	Output	Voltage sense pin. Normally driven low by NS9775, but toggled during interrogation of external CardBus device to detect voltage requirements.
GNT3#	CVS2	Output	Voltage sense pin. Normally driven low by NS9775 but toggled during interrogation of external CardBus device to detect voltage requirements.
REQ1#	CREQ#	Input	Request from external CardBus device to NS9775's internal arbiter.

Table 291: CardBus IO muxing

PCI Signal	CardBus Signal	CardBus type	Comments
REQ2#	CCD1	Input	Card detect pin. Pulled up by system when socket is empty and pulled low when the external CardBus device is present in the socket.
REQ3#	CCD2	Input	Card detect pin. Pulled up by system when socket is empty and pulled low when the external CardBus device is present in the socket.
N/A	CVS1_DET	Input	Voltage sense detect pin. Can be any GPIO input. Used to detect whether the external CardBus device shorts CVS1 to ground.
N/A	CVS2_DET	Input	Voltage sense detect pin. Can be any GPIO input. Used to detect whether the external device shorts CVS2 to ground.
N/A	CPWR[3:0]	Output	Controls to the external power controller that may be providing the power to the CardBus socket. Required only for hot-insertion and hot-removal. Can be any GPIO outputs.

Table 291: CardBus IO muxing

Notes:

- BP_STAT_OUT[0] and PCI_CENTRAL_RSC_n are two strapping pins that must be pulled low to configure the IO and internal arbiter for CardBus. Because CardBus does not have an IDSEL signal, it is pulled high. As a result, NS9775 captures any configuration accesses from the external CardBus device since it is the only other device on the bus.
- The internal arbiter must be used for CardBus applications. Requests to the arbiter from the REQ2# and REQ3# pins, however, must be disabled by clearing the PCIEN_M2 and PCIEN_M3 bits in the PCI Arbiter Configuration register. The arbiter parks the bus only on the bridge — not on the last granted master, as is done for PC I.

CardBus adapter requirements

In a CardBus application, NS9775 is the *adapter*, or *bridge*. The adapter is required to have a set of socket registers that provide socket control and status. The following NS9775 registers support this requirement:

- CardBus Socket Event (see "CardBus Socket Event register" on page 459)
- CardBus Socket Mask (see "CardBus Socket Mask register" on page 460)
- CardBus Socket Present State (see "CardBus Socket Present State register" on page 461)
- CardBus Socket Force Event (see "CardBus Socket Force Event register" on page 464)
- CardBus Socket Control (see "CardBus Socket Control register" on page 467)

CardBus interrupts

The dedicated CINT# signal on the CardBus is connected directly to the interrupt controller in the System Control module, as Interrupt #10 (that is, the same as the INTA# signal for the PCI bus). Table 292 shows the CardBus-related maskable interrupt conditions that are reported to the System Control module's interrupt controller through the PCI arbiter's interrupt.

Bit field	Register
CSTSCHG_CHG	CardBus Socket Event
CCD1_CHG	CardBus Socket Event
CCD2_CHG	CardBus Socket Event
PWR_CHG	CardBus Socket Event
REQ_INTGATE	CardBus Miscellaneous Support
CCLKRUN	PCI Arbiter Interrupt Status

Table 292: CardBus interrupt sources

See the sections on PCI configuration and powered socket configuration, in the *NS9775 Sample Driver Configurations*, for information about configuring NS9775 properly for use with the CardBus.

BBus Bridge

CHAPTER 8

The NS9775 ASIC contains two busses that interconnect the peripherals. The high speed peripherals reside on the AMBA AHB bus. The low speed peripherals reside on the Digi proprietary BBus. The main function of the BBus bridge is to connect the main AHB bus to the proprietary Digi BBus. Both bus interfaces have a master and a slave interface.

BBus bridge functions

The Digi BBus is a low-speed secondary bus that operates at half the AHB clock frequency. The BBus interface houses the slower serial interfaces for USB, IEEE 1284, SPI, and UART, as well as dedicated BBus DMA control, to offload some of the bandwidth demands of the primary AHB bus. The BBus bridge controls the flow of data between the AHB and BBus interfaces.

The BBus bridge provides these functions:

- **BBus arbitration and multiplexing.** The USB and DMA peripheral, in addition to the BBus bridge, can be BBus masters. All BBus peripherals contain a slave interface.
- **Two-channel DMA controller.** The DMA controller performs memory-to-memory transfers across the AHB bus, allowing DMA transfers from an external peripheral to external memory or from external memory to an external peripheral.
- **System boot engine that fetches data from an external SPI-EEPROM and writes it to an external SDRAM.** The boot engine configures the memory controller accordingly, before fetching the contents of the EEPROM. While a serial boot operation takes place, the CPU is held in reset.

Figure 78 shows the four functions of the BBus bridge in relation to the AHB bus and the BBus.

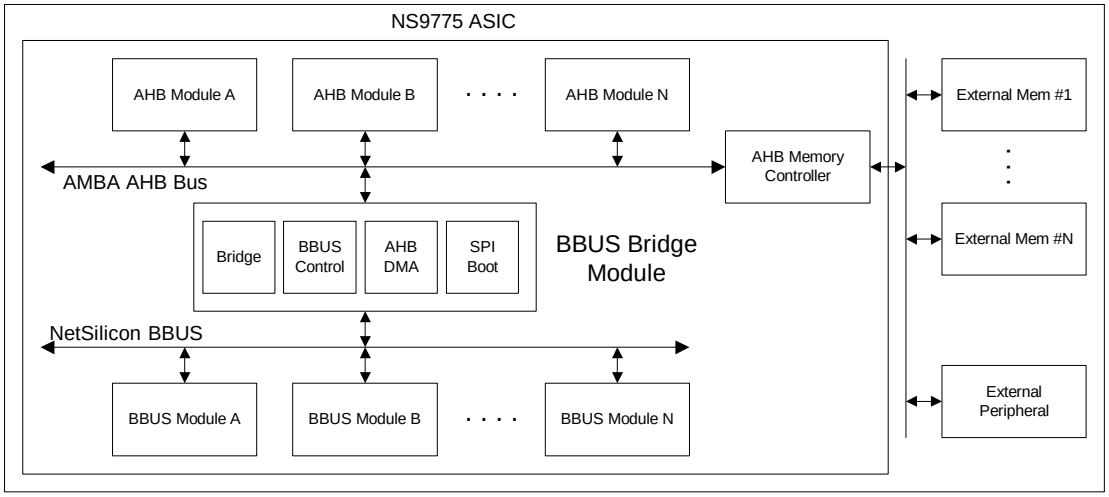


Figure 78: Basic block diagram

Bridge control logic

BBus bridge control logic translates the AHB bus protocol to the BBus protocol and vice versa. The AHB bus can operate at a maximum of 100MHz; the BBus operates at half the AHB clock frequency.

Figure 79 details BBus bridge control logic.

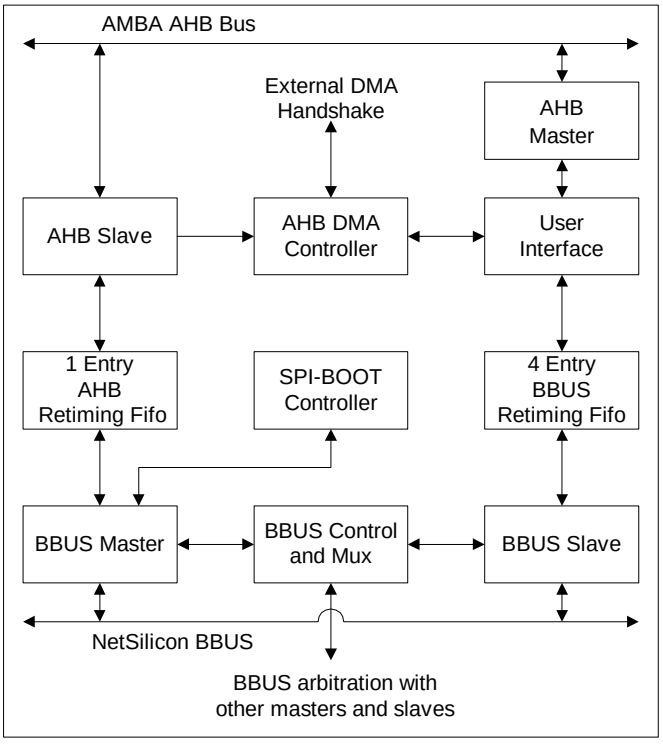


Figure 79: BBus bridge block diagram

Notes:

- The AHB bus and BBus clock domains are asynchronous to each other.
- A 4-entry bidirectional FIFO is implemented in the BBus-to-AHB data path to allow burst transfers.
- The FIFO size matches the maximum burst size supported by the BBus masters.
- The AHB-to-BBus data path does not support burst transfers, allowing only a single entry bidirectional FIFO to be implemented in the data path. FIFO size accommodates only one transaction at a time.

DMA accesses

There are two DMA controllers on the NS9775 BBus. One DMA controller services all BBus peripherals except the USB device; the other is dedicated to the USB device. Each DMA controller contains 16 channels that perform both DMA read and DMA write transactions.

Note: The USB host is a bus mastering BBus peripheral.

- **DMA memory-to-peripheral transfers (DMA read).** DMA read transactions begin with the DMA controller arbitrating for BBus control. When the bus has been granted, the read transaction is presented to the BBus slave interface within the BBus bridge. The command then is passed into the BBus command retiming FIFO, where the user interface picks it up and passes it to the AHB master interface. The AHB master arbitrates for the AHB bus, performs the specified AHB read transaction, and returns the data to the BBus retiming data FIFO. When the BBus slave detects the data in the retiming data FIFO, the BBus slave can respond to the read request from the BBus master.

  The AMBA AHB bus can indicate the burst size at the beginning of a new transfer; the AHB master sets the `hburst[2:0]` signals to the appropriate value. Because the BBus cannot indicate burst size, the user interface always issues a 4-transfer (4-word) request, which goes into the BBus retiming FIFO. When data is transferred to the BBus, as many words as are needed are moved. When the BBus read transaction completes, any words remaining in the retiming FIFO are flushed.

- **DMA peripheral-to-memory transfers (DMA write).** DMA write transactions begin with the DMA controller arbitrating for control of the BBus. Once the bus is granted, the write transaction is presented to the BBus slave interface within the BBus bridge. The BBus slave interface passes the command data to the BBus data retiming FIFO, but retains the command until the BBus transaction completes. At this point, the BBus slave knows the size of the burst (by counting the number of transfers); that information is passed with the command to the BBus retiming command FIFO. When the BBus detects the presence of the command, it passes the command to the AHB master. The AHB master arbitrates for the AHB bus and performs the AHB write transaction.

BBus control logic

BBus control logic consists of a round-robin arbiter to select a new master, the multiplexing logic to provide the new master's signals to the BBus slaves, and address decoding to select the target BBus slave.

BBus bridge masters and slaves

BBus bridge arbitration allows each bus master to control the bus in a round-robin manner. If a bus master does not require the bus resources when its turn comes around, that bus master is skipped until the next round-robin slot. Each potential bus master presents the bus with request and attribute signals. Once the bus grants mastership, the targeted device is selected.

Note: The CPU always is granted mastership when requested, because its transactions are time-sensitive and completed within 4 BBus clock cycles. When the CPU requests use of the bus, it must wait until the current transaction finishes. The CPU then takes mastership and performs its transaction, before the next BBus master with a pending request. When the CPU transaction is finished, the bus grants mastership to the appropriate requesting BBus master.

Table 304 shows the BBus bus master and slave modules.

Module	Master	Slave
BBus bridge	Y	Y
BBus DMA	Y	Y
SER		Y
I2C		Y
1284		Y
USB dev		Y
USB DMA	Y	Y
USB host	Y	Y

Table 304: BBus master and slave modules

Cycles and BBus arbitration

During a normal cycle, each bus master cycle is allowed only one read/write cycle if another bus master is waiting. There are two exceptions to this rule: burst transactions and read-modify-write transactions.

In a burst transaction, the master can perform more than one read or write cycle. In a read-modify-write transaction, the bus master performs one read and write cycle to the same location.

BBus peripheral address map (decoding)

The BBus address map is divided to allow access to the internal modules and external resources routed through the internal peripherals. The BBus configuration registers are located at base address 0xA040 0000 and are dedicated a 1 MB address space. The BBus peripherals are located at base address 0x9000 0000 and span a 256 MB address space. Each BBus peripheral, with the exception of the SER port controllers, resides in a separate 1 MB address space.

Table 305 specifies the address space given to each peripheral.

Base address	Peripheral
0x9000 0000	BBus DMA controller
0x9010 0000	USB controller
0x9020 0000	SER Port #B
0x9020 0040	SER Port #A
0x9030 0000	SER Port #C
0x9030 0040	SER Port #D
0x9040 0000	IEEE-1284 controller
0x9050 0000	I2C controller
0x9060 0000	BBus utility

Table 305: BBus peripheral address map

Two-channel AHB DMA controller (AHB bus)

Each DMA channel moves data from the source address to the destination address. Transfers can be specified as burst-oriented to maximize AHB bus efficiency. All transfers are executed in two steps:

1 Data is moved from the source address to an 8-entry buffer in the DMA control logic.

2 Data is moved from the 8-entry buffer to the destination address.

These steps are repeated until the DMA transfer is complete. Note that optimum performance is achieved when the source and destination addresses are word-aligned.

Initiating a DMA transfer

There are two ways to initiate a DMA transfer: processor-initiated and external-peripheral initiated.

When the processor initiates the DMA transfer, it performs these steps:

1 Sets up the required buffer descriptors.

2 Configures the appropriate DMA Channel 1/2 Control register (see "DMA Channel 1/2 Control register" on page 503).

3 Writes a 1 to the channel enable (CE) and channel go (CG) fields in the DMA Channel 1/2 Control register (see "DMA Channel 1/2 Control register" on page 503).

The external peripheral initiates a DMA transfer by asserting the appropriate REQ signal. Software must set up the required buffer descriptors and configure the DMA Channel 1/2 Control register (including setting the CE field to 1) before asserting the REQ signal.

DMA buffer descriptor

All DMA channels in NS9775 use a buffer descriptor. When a DMA channel is activated, it reads the DMA buffer descriptor pointed to by the Buffer Descriptor Pointer register (see "Buffer Descriptor Pointer register" on page 502). A DMA buffer descriptor is always fetched using an AHB INCR4 transaction, to maximize AHB bus bandwidth.

When the current descriptor is retired, the next descriptor is accessed from a circular buffer.

Each DMA buffer descriptor requires four 32-bit words to describe a transfer. Circular buffers of 1024 bytes contain multiple buffer descriptors. The first buffer descriptor address is provided by the DMA channel's Buffer Descriptor Pointer register. Subsequent buffer descriptors are found adjacent to the first descriptor. The final buffer descriptor is defined with its W bit set. When the DMA channel encounters the W bit, the channel wraps around to the first descriptor.

Each DMA channel can address a maximum of 64 buffer descriptors, each consisting of 16 bytes. Configuring the DMA channel for more than the maximum number of buffer descriptors results in unpredictable behavior.

Figure 80 shows the DMA buffer descriptor. Table 306 describes each section.

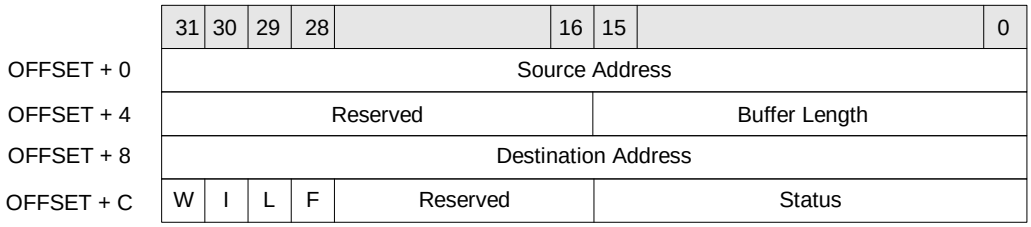


Figure 80: BBus bridge DMA buffer descriptor

Field/Section	Description
Source address	Identifies the starting location of the source data. The source address can be aligned to any byte boundary. Optimum performance results when the source address is aligned on a word boundary
Buffer length	Indicates the number of bytes to move between the source and the destination. After completing the transfer, the DMA controller updates this field with the actual number of bytes moved.
Destination address	Identifies the beginning of the location to which the source data will be moved. The destination address can be aligned to any byte boundary. Optimum performance results when the destination address is aligned on a word boundary.

Table 306: BBus bridge DMA buffer descriptor definition

Field/Section	Description
W	The **wrap** bit. When set, this bit tells the DMA controller that this is the last buffer descriptor within the continuous list of descriptors. The next buffer descriptor is found using the initial DMA channel buffer descriptor pointer. When the wrap bit is not set, the next buffer descriptor is found using an offset of 0x10 from the current buffer descriptor.
I	The **interrupt** bit. Tells the DMA controller to issue an interrupt to the CPU when the buffer is closed due to normal channel completion. The interrupt occurs no matter what the normal completion interrupt enable configuration is for the DMA channel.
L	The **last** bit. When set, this bit tells the DMA controller that this buffer descriptor is the last descriptor that completes an entire message frame. The DMA controller uses this bit to assert the normal channel completion status when the byte count reaches zero. If this bit is set, the DMA controller remains in the IDLE state after asserting the normal channel completion status. A write to the CE field in the DMA Channel 1/2 Control register re-enables the DMA channel.
F	The **full** bit. When set, this bit indicates that the buffer descriptor is valid and can be processed by the DMA channel. ■ The DMA channel clears this bit after completing the transfer(s). ■ The DMA channel doesn't try a transfer with the F bit clear. ■ The DMA channel enters an IDLE state after fetching a buffer descriptor with the F bit cleared. ■ When the device driver modifies the F bit, it must also write a 1 to the CE bit in the DMA Channel 1/2 Control register to activate the idle channel.
Reserved	Write zero to this field.
Status	Not used. Read back 0x0000.

Table 306: BBus bridge DMA buffer descriptor definition

Descriptor list processing

When a DMA controller has completed the operation specified by the current buffer descriptor, the controller clears the F bit and fetches the next buffer descriptor. A

DMA channel asserts the NRIP field in the DMA Status and Interrupt Enable register (see "DMA Status and Interrupt Enable register" on page 506) and returns to the idle state after fetching a buffer descriptor with the F bit in the incorrect state.

Peripheral DMA read access

Figure 81 and Figure 82 show how the DMA engine performs read accesses of an external peripheral. The CLK signal shown is for reference, and its frequency is equal to 1/2 the speed grade of the part. The rising edge of the READ_EN signal coincident with the assertion of the chip select signal must cause the peripheral to place the next quantum of data on the bus. The width of the READ_EN signal is always equal to one reference CLK period. The delay from the falling edge of CS# to the rising edge of ACK is always equal to one reference CLK period. The width of the CS# assertion is defined in the Static Memory Read Delay register (see "Static Memory Read Delay 0–3 registers" on page 309).

DMA read accesses from an external peripheral are treated as asynchronous operations by the NS9775. It is critical that the required width of the CS# assertion be computed correctly and programmed into the Static Memory Read Delay register. Total access time can be computed as shown:

$$\text{Total access time} = T_a + T_b + T_c + 10.0$$

The variables are defined as follows:

T_a = Peripheral read access time

T_b = Total board propagation including buffers

T_c = One reference CLK cycle period

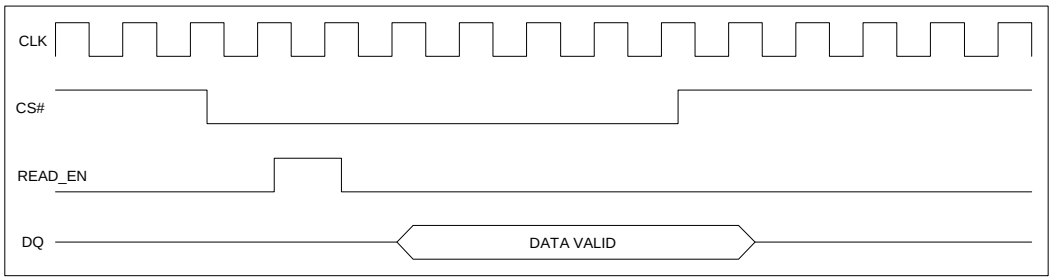


Figure 81: Peripheral DMA single read access

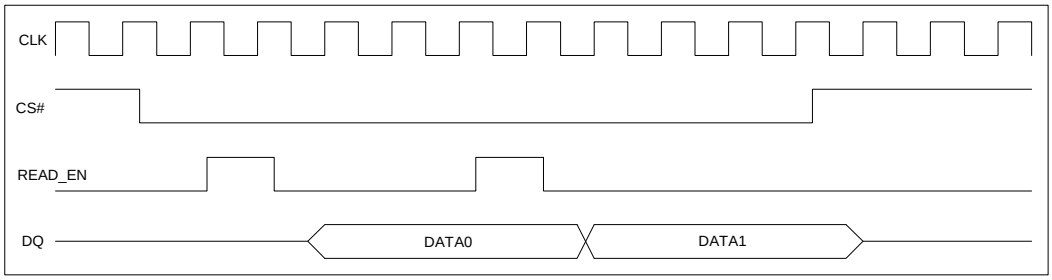


Figure 82: Peripheral DMA burst read access

Peripheral DMA write access

Figure 83 and Figure 84 show how the DMA engine performs write accesses of an external peripheral. The clock signal shown is for reference, and its clock frequency is equal to 1/2 the speed grade of the part. Data should be written on the rising edge of the WE# signal. Data and control signals are always held after the rising edge of WE# for one reference CLK cycle. The CS# signal is guaranteed to be deasserted for at least one CLK cycle between successive peripheral write accesses. The widths of the CS# assertion and the WE# assertion are defined using the Static Memory Write Delay register and the Static Memory Write Enable Delay register in the Memory Controller (see "Static Memory Read Delay 0–3 registers" on page 309 and "Static Memory Write Enable Delay 0–3 registers" on page 307).

Note that the ACK signal is not used during peripheral DMA write accesses.

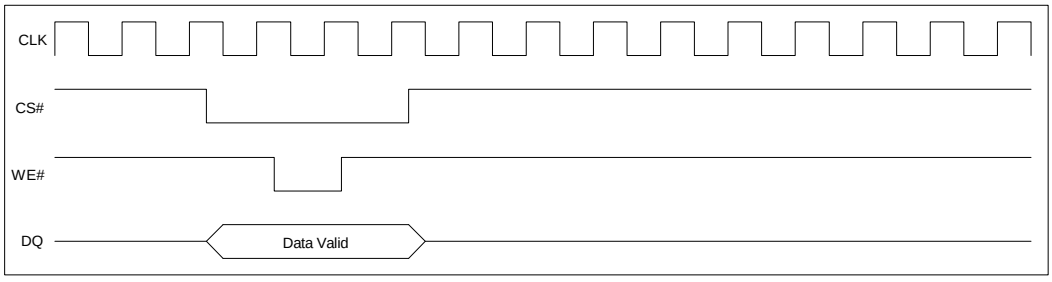


Figure 83: Peripheral DMA single write access

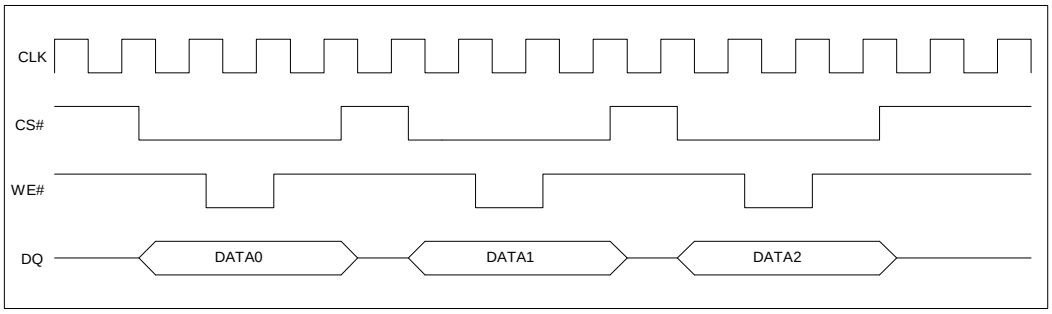


Figure 84: Peripheral DMA burst write access

Peripheral REQ signaling

An external peripheral indicates that it can accept or provide data by asserting its REQ signal. The AHB DMA controller fully processes one buffer descriptor for each assertion of the external peripheral's REQ signal.

The AHB DMA controller state machine executes these steps for each assertion of the REQ signal.

1. Fetch the next buffer descriptor in the list from system memory.
2. Read the number of bytes specified in the buffer length field from the address specified in the source address field. This data is placed in an on-chip temporary buffer.
3. Write the data from the on-chip temporary buffer to the address specified in the source address field.
4. Retire the buffer descriptor to system memory.
5. Assert any specified interrupts to the CPU.
6. Return to the idle condition and wait for the next assertion of the external peripheral's REQ signal.

For memory-to-memory DMA transfers that are initiated by software writing a 1 to the CG field in the DMA Channel 1/2 Control register, the peripheral signal REQ is ignored.

Design Limitations

The AHB DMA logic contains several design limitations. Carefully consider these limitations when making system level implementation decisions:

- The AHB DMA control logic is designed to operate on four-byte quantities, which limits the minimum number of accesses that the memory controller can perform on narrow external peripherals. Accesses to an 8-bit peripheral will always occur in multiples of four. Accesses to a 16-bit peripheral will always occur in multiples of two. Asserting the REQ signal when the peripheral is unable to meet the above conditions results in unpredictable system behavior.
- The length field in the buffer descriptor must be set to a value equal to the burst length multiplied by four. The burst length is specified in the SB/DB field in the DMA Channel 1/2 Control register.
- The peripheral can assert the REQ signal no more often than the AHB DMA response latency for the given system (see "Calculating AHB DMA response latency" on page 492).
- The REQ signal is an asynchronous input to the NS9775. For a REQ signal assertion to be found by the control logic, it must be asserted for no less than 4 AHB clock cycles and no more than 20 AHB clock cycles.
- The AHB DMA channels are allocated the unused BBus peripheral bandwidth, which limits the bandwidth available to the AHB DMA channels. Minimum bandwidth requirements can be met by allocating more AHB bus timeslots to the BBus master using the BRC registers in the System Control module.
- The AHB DMA channels provide no latency guarantee because they do not directly attach to the AHB bus. Allocating more system bandwidth reduces the worst case latency. In a fully loaded system, the response to the REQ signal assertion can be as long as 83us.

Calculating AHB DMA response latency

AHB DMA controller latency is defined as the time between the assertion of the peripheral's REQ signal and the AHB DMA channel being granted access to the AHB bus. Response latency is a function of the number of AHB timeslots given to the BBus and the number of BBus peripherals in use. Note that the BBus peripherals

transferring data in non-DMA mode do not contribute to the calculation. The worst case AHB DMA response latency occurs when all of the BBus peripherals perform these operations within several microseconds of each other:

- Move the remaining data in or out of the data buffer.
- Close the buffer descriptor.
- Open a new buffer descriptor.
- Begin processing the new data buffer. This can be two steps for a transmitter.

Two AHB bandwidth calculations are defined here. The first scheme shows the worst case, where the BBus is given one out of ten AHB timeslots. The second scheme shows the best case, where the BBus is given one out of every four AHB timeslots.

Worst case:

```
AHB access = ((16 * 10 * 2) / 200 MHz) = 1.60us
```

This AHB access pattern looks like this:

```
Cpu, Erx, Cpu, Etx; Cpu, Lcd, Cpu, Pci; Cpu, BBus
```

Best case:

```
AHB access = ((16 * 4 * 2) / 200 MHz) = 0.64us
```

This AHB access pattern looks like this:

```
Cpu, Erx, Cpu, BBus; Cpu, Etx, Cpu, BBus; Cpu, Lcd, Cpu,
BBus; Cpu, Pci; Cpu, BBus
```

Each receive channel contributes four AHB accesses to the calculation. Each transmit channel contributes five AHB accesses to the calculation. The USB device (or USB host) and IEEE 1284 are half-duplex-only peripherals, so only the transmit channel needs to be accounted for.

Also take into account adjustment for AHB DMA channel overhead: two if one DMA channel is in use and six if both DMA channels are in use. The worst case and best case equations for two DMA channels work out as shown:

Worst case latency = `1.60us * ((#Receive * 4) + (#Transmit * 5) + 6)`

Best case latency = `0.64us * ((#Receive * 4) + (#Transmit * 5) + 6)`

In a fully loaded system with four UARTs, IEEE 1284, and USB, the worst case latency is 83.2us and the best case latency is 33.28us.

Static RAM chip select configuration

The AHB DMA controller accesses an external peripheral using the external memory bus and one of the static RAM chip select signals (st_cs_n[N]). This table describes how to program the static RAM chip select control registers for access using the AHB DMA controller.

- Fields not explicitly listed should be left in the reset state.
- Fields listed but not defined must be defined by the user.

Register Name	Field	Value	Comment
Configuration	PB	1	System requirement.
	PM	user defined	Set to 1 if it is not necessary for the chip select signal to toggle for each access.
	MW	user defined	N/A
Read Delay	WTRD	user defined	Compute the total delay using the equation provided in "Peripheral DMA read access" on page 489. The total delay should be divided by the AHB clock period to produce this value. Round up any fractional result.
Page Read Delay	WTPG	user defined	For most applications, this value will be the same as the value for WTRD.
Output Enable Delay	WOEN	user defined	If the ACK signal is used to initiate a peripheral read, this field should be set to 0. If signal st_oe_n is used to initiate a peripheral read, this field should be set to (at least) 1.
Write Enable Delay	WWEN	user defined	For most applications, this field can be left in the default state.
Write Delay	WTWR	user defined	For most applications, this field can be left in the default state.
Turn Delay	WTTN	user defined	For most applications, this field can be left in the default state.

Table 307: Static RAM chip select configuration

Interrupt aggregation

All the peripherals on the BBus, as well as AHB DMA channels 1 and 2 in the BBus bridge, can interrupt the CPU when attention is required. These interrupts are aggregated in the BBus bridge, and a single interrupt is presented to the System Control Module on the `bbus_int` signal.

This function is performed in the BBus bridge because it allows the processor to quickly identify which BBus peripheral(s) is requesting attention. (See "BBus Bridge Interrupt Status register" on page 509 for more information.)

Note: The interrupt(s) must be serviced in the peripheral in which the interrupt(s) originated.

Bandwidth requirements

A single AHB timeslot is sufficient to support the ideal maximum bandwidth of the BBus peripherals plus overhead for DMA buffer descriptors. The maximum case occurs with four SPI masters, IEEE 1284, and either USB device or USB host.

- The SPI master interfaces support a maximum of 6.25 Mbps of full duplex traffic.
- The IEEE-1284 interface supports a maximum of 2 Mbps of full duplex traffic.
- The USB supports a maximum of 12 Mbps of full duplex traffic.

The total peripheral bandwidth is 64Mbps. Adding 8 Mbps for DMA buffer descriptors brings the total requirement to 9 MBps, less than one AHB timeslot with a full 16-slot rotation.

Important: Be aware that the AHB DMA channels and the BBus peripherals share an AHB timeslot. The BBus peripherals are always given a higher priority than the AHB DMA channels. The busier the BBus peripherals, then, the less available bandwidth for the AHB DMA channels.

SPI-EEPROM boot logic

SPI-EEPROM boot logic is enabled by strapping off the boot_cfg pins to the boot from SDRAM setting in the Miscellaneous System Configuration and Status register. Table 308 shows the related boot settings.

boot_cfg [1:0]	Description
00	Boot from 8-bit ROM or flash
01	Boot from 16-bit ROM or flash
10	Boot from 32-bit ROM or flash
11	Boot from SDRAM using SPI-EEPROM

Table 308: NS9775 boot configuration

When enabled, the boot logic copies the contents of an SPI-EEPROM to system memory, allowing you to boot from a low-cost serial memory. The boot logic works by interfacing to SER port B using the BBus — performing the transactions required to copy the boot code from SPI-EEPROM to external memory (see

Important: SPI-EEPROM must be connected to SER port B; the boot logic does not communicate with any other SER port.

Calculation and example

This equation calculates the amount of time, in seconds, required to copy the contents of the SPI-EEPROM to external memory:

$Time = (1 / freq) * EEPROM_{SIZE}$

Example

SPI master clock frequency = 1.5 MHz

SPI-EEPROM = 256 Kb

Time for operation to complete = 175 ms

Serial Channel B configuration

When exiting the power-on reset state, serial channel B is in SPI master mode, which facilitates communication with the external SPI-EEPROM. When the copy operation is

complete, serial channel B is returned to its default reset state. The next table shows which configuration fields are updated by hardware, allowing the SPI master interface to operate.

Register	Field	Value	Description
Control A	CE	0x1	Enable the channel
Control A	WLS	0x3	8 data bits per word
Control B	CSPOL	0x0	Chip select polarity to active low
Control B	MODE	0x2	SPI master mode
Control B	BITORDR	0x1	Bit order to MSB first
Bit Rate	EBIT	0x1	Enable the bit rate generator
Bit rate	TMODE	0x1	Synchronous timing
Bit rate	CLKMUX	0x1	Select BBus clock as reference
Bit rate	TXCINV	0x1	Transmit clock inverted
Bit rate	N	0x00F	Create ~1.5 MHz SPI clock

Table 309: SPI master mode boot configuration

Memory Controller configuration

Note: See your ARM documentation for complete information about the memory controller.

The memory controller exits the reset state in non-operational mode. This requires the SPI-EEPROM boot logic to configure the memory controller as well as the external SDRAM before any memory access.

Important: The information required to configure the memory controller and the external SDRAM must be stored in a configuration header in the SPI-EEPROM in a contiguous block starting at address zero. Each entry in the header, with the exception of the pad entry, must be 4 bytes in length.

The size of the configuration header varies from 128 bytes to 130 bytes, due to the variable length nature of the SPI-EEPROM read command. Table 310 shows the order and contents of the configuration header.

EEPROM entry	Description
Pad entry	Variable length entry that ranges from 0 bytes to 2 bytes in length. The field length is computed by subtracting the length of the read command (including the address field) from 4. **Example** A 256 Kb EEPROM requires a 1-byte read command followed by a 2-byte address, resulting in a pad entry length of 1: `4-(1+2) = 1`
Num words	Total number of words to fetch from the SPI-EEPROM. The total must include the 32-word header plus the initial discarded word. `# words = ((`S_1 `+` S_2`) / 4) + 1)` S_1 = Code image size in bytes S_2 = header = 128 bytes
SDRAM config	All SDRAM components contain a Mode register, which has control information required to successfully access the component. The fields (available in any SDRAM specification) are defined as follows: ■ Burst length: 4 for 32-bit data bus, 8 for 16-bit data bus ■ Burst type: Sequential ■ CAS latency: Component-specific; 2 or 3 ■ OpMode: Standard ■ Write burst mode: Programmed burst length This value must be left-shifted by the number of row bits in the selected components. For example, `4Mx16` components can be combined to create a 32-bit bus. These parts require 12 row address bits. Assuming a CAS2 access, the Mode register contents would be `0x22`. This value is shifted 12 places to the left (`0x00022000`) to form the value in the SDRAM config field.
Config register	See the Memory Controller chapter.
DynamicRefresh	See the Memory Controller chapter. For example, the value of this entry is `0x00000030` given a 100 MHz AHB clock and a 7.8125µs refresh period.
DynamicReadConfig	See the Memory Controller chapter.

Table 310: ARM boot configuration

EEPROM entry	Description
DynamictRP	See the Memory Controller chapter.
DynamictRAS	See the Memory Controller chapter.
DynamictSREX	See the Memory Controller chapter.
DynamictAPR	See the Memory Controller chapter.
DynamictDAL	See the Memory Controller chapter.
DynamictWR	See the Memory Controller chapter.
DynamictRC	See the Memory Controller chapter.
DynamictRFC	See the Memory Controller chapter.
DynamictXSR	See the Memory Controller chapter.
DynamictRRD	See the Memory Controller chapter.
DynamictMRD	See the Memory Controller chapter.
DynamicConfig0	Field B (buffer enable, in the DynamicConfig0 register) should be set to 0 (buffers disabled). The buffers will be enabled by hardware as part of the boot process. See your ARM documentation.
DynamicRasCas0	See the Memory Controller chapter.
Reserved	The remaining bytes are undefined. The final byte address of header is one of the following, depending on the pad entry length: ■ 0x7F ■ 0x80 ■ 0x81
Boot code	Must immediately follow the configuration header. The first byte address of the boot code is one of the following, depending on the pad entry length: ■ 0x80 ■ 0x81 ■ 0x82

Table 310: ARM boot configuration

SDRAM boot algorithm

Note: The SDRAM boot logic communicates only with serial channel B.

These steps describe the SDRAM boot algorithm:

1. Pins `boot_cfg[1:0]` are both strapped high.

   Power-on reset is deasserted.

   The CPU is held in reset by the SPI-EEPROM boot module.

   Serial channel B comes out of reset in SPI master mode.

2. A SPI-EEPROM read command at address zero is written to the Fifo Data register. This is followed by seven more NOP entries.
3. The RXFDB and RRDY fields are monitored in Status Register A. Only complete words are read from the Fifo Data register. This process is repeated until four words have been received. An internal word counter tracks how many words have been taken from the SPI-EEPROM (see Table 311, "Boot algorithm actions," on page 500 for information about any actions taken).
4. The state machine enters a loop where four NOP words are written to the Fifo Data register and four words are read from the Fifo Data register. The RXFDB and RRDY fields are continuously monitored in Status Register A. The Fifo Data register is read only when a valid word is present.
5. The CPU is taken out of reset and serial channel B is placed into reset. Normal operation begins with the ARM fetching an instruction from system memory address `0x00000000`.

Internal word counter	Action(s) taken
0x01	This word is discarded. The word is composed of the bytes shifted in while the read command and address are being shifted out, as well as the pad entry in the header.
0x02	Num words entry. This entry is saved locally.
0x03	SDRAM config entry. This entry is saved locally.
0x04 – 0x14	Memory controller entries. These entries are written to the appropriate memory controller register.

Table 311: Boot algorithm actions

Internal word counter	Action(s) taken
0x015	Field **I** in the memory controller Dynamic Control register is set to *PALL*, which allows several refresh operations to occur while the next 12 words are shifted in from the SPI-EEPROM.
0x016 – 0x20	No action taken. The word is discarded.
0x021	■ Field **I** in the memory controller Dynamic Control register is set to *MODE*. A system memory read operation is performed, to the address specified by the SDRAM config entry. This configures the external SDRAM devices. ■ Field **I** in the memory controller Dynamic Control register is set to *NORMAL*. Dynamic Configuration Register 0 is read and field **B** is set as required by the memory controller for normal operation.
0x022 – *End*	Each word is written to system memory starting at address 0x00000000. *End* is defined by the internal word counter matching the num words entry (0x02)

Table 311: Boot algorithm actions

BBus Bridge Control and Status registers

The BBus configuration registers are located at base address 0xA040.0000. All configuration registers are accessed with zero wait states. Table 312 lists the configuration and status registers in the BBus Bridge module.

All configuration registers must be accessed as 32-bit words and as single accesses only. No bursting is allowed.

Address	Register
A040 0000	DMA Channel 1 Buffer Descriptor Pointer
A040 0004	DMA Channel 1 Control register
A040 0008	DMA Channel 1 Status and Interrupt Enable

Table 312: BBus Bridge module registers

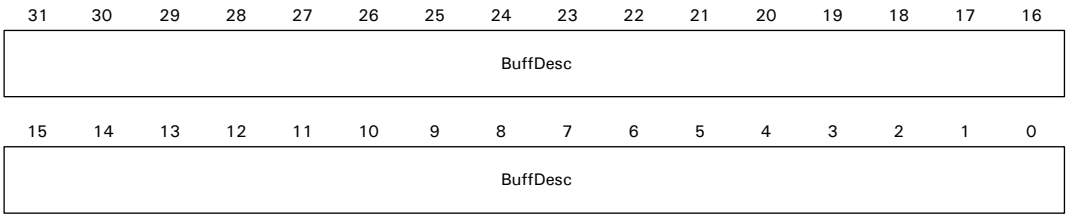
Address	Register
A040 000C	DMA Channel 1 Peripheral Chip Select
A040 0020	DMA Channel 2 Buffer Descriptor Pointer
A040 0024	DMA Channel 2 Control register
A040 0028	DMA Channel 2 Status and Interrupt Enable
A040 002C	DMA Channel 2 Peripheral Chip Select
A040 0100	BBus Bridge Interrupt Status
A040 1004	BBus Bridge Interrupt Enable

Table 312: BBus Bridge module registers

Buffer Descriptor Pointer register

Address: A040 0000 / 0020

This register contains a 32-bit pointer to the first buffer descriptor in a contiguous list of buffer descriptors. The BBus bridge contains a Buffer Descriptor Pointer register for each DMA channel; each register is 16 bytes in length.



Register bit assignment

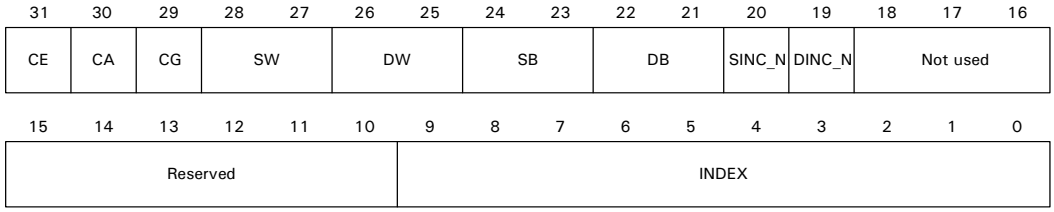
Bit(s)	Access	Mnemonic	Reset	Description
D31:00	RW	BuffDesc	0x00000000	**Buffer descriptor** 32-bit pointer to a buffer descriptor.

Table 313: Buffer Descriptor Pointer register bit definition

DMA Channel 1/2 Control register

Address: A040 0004 / 0024

This register contains required DMA transfer control information. The BBus bridge contains a DMA Channel Control register for each channel.



Register bit assignment

Bit(s)	Access	Mnemonic	Reset	Description
D31	R/W	CE	0	**Channel enable** Enables and disables DMA operations, as wanted. Write a 1 to this field after a DMA channel has entered the IDLE state for any reason, to initiate additional DMA transfers.
D30	R/W	CA	0	**Channel abort** When set, causes the current DMA operation to complete, then closes the buffer.
D29	R/W	CG	0	**Channel go** When set, causes the DMA channel to exit the IDLE status and begin a DMA transfer. **Note:** The CE field must also be set. This allows software to initiate a memory-to-memory DMA transfer. External peripheral signal REQ is not used during memory-to-memory DMA transfers.

Table 314: DMA Channel 1/2 Control register bit definition

Bit(s)	Access	Mnemonic	Reset	Description
D28:27	R/W	SW	0	**Source width** Defines the size of the source data bus. Used only for peripheral to memory transfers. 00 8 bits 01 16 bits 10 32 bits 11 Undefined
D26:25	R/W	DW	0	**Destination width** Defines the size of the destination data bus. Used only for memory to peripheral transfers. 00 8 bits 01 16 bits 10 32 bits 11 Undefined
D24:23	R/W	SB	0	**Source burst** 00 1 01 2 (Recommended for 8-bit devices) 10 4 (Recommended for 16-bit devices) 11 8 (Recommended for 32-bit devices) Defines the AHB maximum burst size allowed when reading from the source.
D22:21	R/W	DB	0	**Destination burst** 00 1 01 2 (Recommended for 8-bit devices) 10 4 (Recommended for 16-bit devices) 11 8 (Recommended for 32-bit devices) Defines the AHB maximum burst size when writing to the destination. This field must be set to the same value as the source burst field.
D20	R/W	SINC_N	0	**Source address increment** 0 Increment source address pointer 1 Do not increment source address pointer Controls whether the source address pointers are incremented after each DMA transfer.

Table 314: DMA Channel 1/2 Control register bit definition

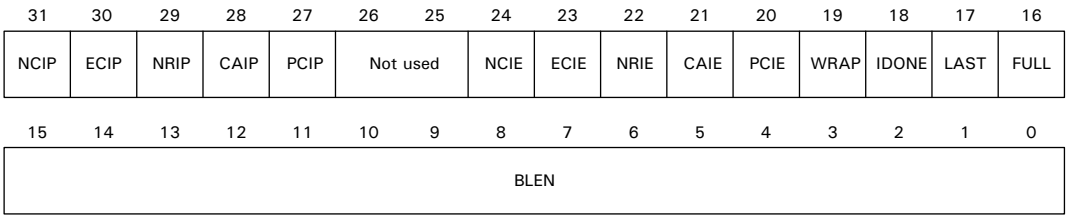
Bit(s)	Access	Mnemonic	Reset	Description
D19	R/W	DINC_N	0	**Destination address increment** 0 Increment destination address pointer 1 Do not increment destination address pointer Controls whether the destination address pointers are incremented after each DMA transfer.
D18:16	R/W	POL	0	Always set this field to 0.
D17	R/W	MODE	0	**Fly-by mode** 0 Defines a peripheral to memory fly-by write DMA transfer 1 Defines a memory-to-peripheral fly-by read DMA transfer Defines the direction of data movement for fly-by DMA transfers. This field is not used for memory-to-memory DMA transfers initiated by writing the CG field in the DMA Channel 1/2 Control register.
D16	R/W	RST	0	**Reset** Forces a reset of the DMA channel. Writing a 1 to this field forces all fields in the DMA Channel 1/2 Control register, *except the INDEX field,* to the reset state. The INDEX field is written with a value specified on signals `ahb_wdat[9:0]`. This field always reads back a 0. Writing a 1 to this field while the DMA channel is operational results in unpredictable behavior.
D15:10	N/A	Reserved	N/A	N/A
D09:00	R	INDEX	0	**Index value** Identifies the current byte offset pointer relative to the buffer descriptor pointer. This field can be written only when the RST field is being written to a 1.

Table 314: DMA Channel 1/2 Control register bit definition

DMA Status and Interrupt Enable register

Address: A040 0008 / 0028

The DMA Status and Interrupt Enable register contains the DMA transfer status and control information used for generating AHB DMA interrupt signals. The BBus bridge contains a DMA Status and Interrupt Enable register for each DMA channel.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31	RW1TC	NCIP	0	**Normal completion interrupt pending** Set when a buffer descriptor has been closed. A normal DMA completion occurs when the BLEN count expires to 0 and the L bit in the Buffer descriptor is set, or when the peripheral device signals completion.
D30	RW1TC	ECIP	0	**Error completion interrupt pending** Set when the DMA channel finds either a bad buffer descriptor pointer or a bad data buffer pointer. When ECIP is set, the DMA channel stops until firmware clears the ECIP bit. The DMA channel does not advance to the next buffer descriptor. When firmware clears ECIP, the buffer descriptor is tried again from where it left off. You can use the CA bit in the DMA Channel 1/2 Control register to abort the current buffer descriptor and go to the next buffer descriptor.

Table 315: DMA Status and Interrupt Enable register bit definition

Bits	Access	Mnemonic	Reset	Description
D29	RW1TC	NRIP	0	**Buffer not ready interrupt pending** Set when the DMA channel finds a buffer descriptor whose F bit is in the incorrect state. The F bit must be set in order for the fetched buffer descriptor to be considered valid. If the bit is not set, the descriptor is considered invalid and the NRIP bit is set. When NRIP is set, the DMA channel stops until firmware clears the bit. The DMA channel does not advance to the next buffer descriptor.
D28	RW1TC	CAIP	0	**Channel abort interrupt pending** Set when the DMA channel finds the CA bit set in the DMA Channel 1/2 Control register. When CAIP is set, the DMA channel stops until firmware clears the bit. When CAIP is cleared, the DMA channel automatically advances to the next buffer descriptor. The CA bit must be cleared, through firmware, before CAIP is cleared. Failure to reset the CA bit causes the subsequent buffer descriptor to abort.
D27	RW1TC	PCIP	0	**Premature complete interrupt pending** Set when a DMA transfer is terminated by assertion of the `dma_done` signal. NCIP is set when PCIP is set, for backward compatibility.
D26:25	R/W	Not used	0	Always set this field to 0.
D24	R/W	NCIE	0x0	**Enable NCIP interrupt generation**
D23	R/W	ECIE	0x0	**Enable ECIP interrupt generation** Always enable during normal operation.
D22	R/W	NRIE	0x0	**Enable NRIP interrupt generation**
D21	R/W	CAIE	0x0	**Enable CAIP interrupt generation** Always enable during normal operation.
D20	R/W	PCIE	0x0	**Enable PCIP interrupt generation**
D19	R	WRAP	0x0	Debug field, indicating the last descriptor in the buffer descriptor list.

Table 315: DMA Status and Interrupt Enable register bit definition

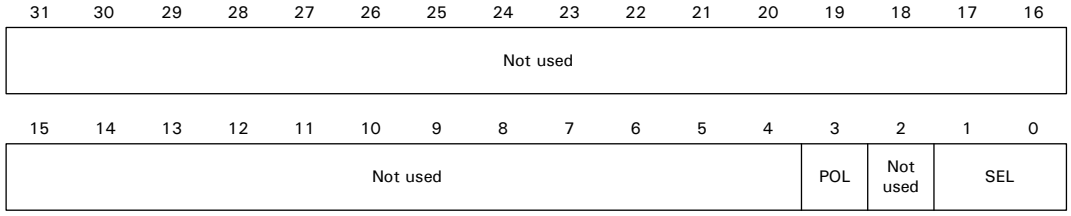
Bits	Access	Mnemonic	Reset	Description
D18	R	IDONE	0x0	Debug field, indicating an interrupt on done occurrence.
D17	R	LAST	0x0	Debug field, indicating the last buffer descriptor in the current data frame.
D16	R	FULL	0x0	Debug field, indicating the status of the F bit from the current DMA buffer descriptor.
D15:00	R	BLEN	0x0000	Debug field, indicating the remaining byte transfer count.

Table 315: DMA Status and Interrupt Enable register bit definition

DMA Peripheral Chip Select register

Address: A040 000C / 002C

The DMA Peripheral Chip Select register contains the DMA peripheral chip select definition. The BBus bridge contains a DMA Peripheral Chip Select register for each channel.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:04	R/W	Not used	0	Always set to 0.
D03	R/W	POL	0	**Chip select polarity** Defines the polarity of the memory interface chip select signal (`stcsout[n]_n`) connected to the external peripheral. 0 Defines an active high signal 1 Defines an active low signal

Table 316: DMA Peripheral Chip Select register

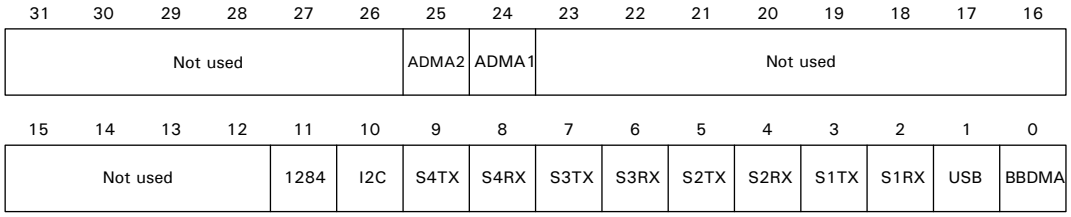
Bits	Access	Mnemonic	Reset	Description
D02	R/W	Not used	0	Always set to 0.
D01:00	R/W	SEL	0	**Chip select selection** Defines which of the four memory interface chip select signals (`stcsout[n]_n`) is connected to the external peripheral. **Value** **Chip select** 0 CS[0] 1 CS[1] 2 CS[2] 3 CS[3] **Note:** This field is not used for memory-to-memory transfers.

Table 316: DMA Peripheral Chip Select register

BBus Bridge Interrupt Status register

Address: A040 1000

This register contains the interrupt status of the BBus peripherals. All interrupts must be serviced in the originating module.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:26	R	Not used	00	Always set this field to 0.
D25	R	ADMA2	0	AHB DMA channel #2 has asserted its interrupt.

Table 317: BBus Bridge Interrupt Status register

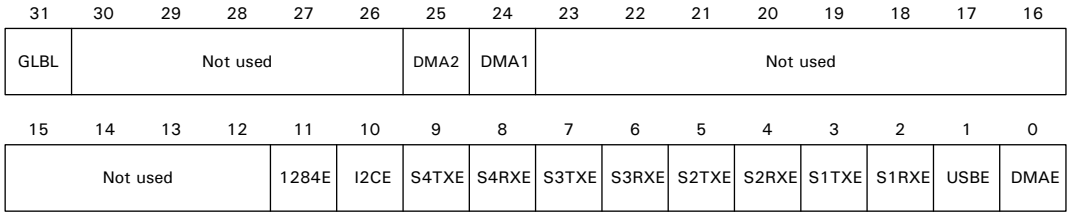
Bits	Access	Mnemonic	Reset	Description
D24	R	ADMA1	0	AHB DMA channel #1 has asserted its interrupt.
D23:13	R	Not used	0x000	Always set this field to 0.
D12	R	Not used	0	Always write to 0.
D11	R	1284	0	IEEE-1284 module has asserted its interrupt.
D10	R	I2C	0	I2C module has asserted its interrupt.
D09	R	SDTX	0	SER transmit module D has asserted its interrupt.
D08	R	SDRX	0	SER receive module D has asserted its interrupt.
D07	R	SCTX	0	SER transmit module C has asserted its interrupt.
D06	R	SCRX	0	SER receive module C has asserted its interrupt.
D05	R	SATX	0	SER transmit module A has asserted its interrupt.
D04	R	SARX	0	SER receive module A has asserted its interrupt.
D03	R	SBTX	0	SER transmit module B has asserted its interrupt.
D02	R	SBRX	0	SER receive module B has asserted its interrupt.
D01	R	USB	0	USB module has asserted its interrupt.
D00	R	BBDMA	0	BBus DMA module has asserted its interrupt.

Table 317: BBus Bridge Interrupt Status register

BBus Bridge Interrupt Enable register

Address: A040 1004

The BBus Bridge Interrupt Enable register allows you to enable or disable BBus interrupts on an individual basis as well as a global basis. Writing a 1 to a bit enables the interrupt, allowing it to be included in the aggregate signal that is sent to the vector interrupt controller in the System Control module. These fields affect only the generation of the signal sent to the vector interrupt controller (VIC); they do not affect the originating modules.



Register bit assignment

Note: Enable = Set to 1.

Bits	Access	Mnemonic	Reset	Description
D31	R/W	GLBL	0	Enable the aggregate interrupt signal to propagate to the VIC in the System Control module.
D30:26	R/W	Not used	0	Always set this field to 0.
D25	R/W	DMA2	0	Enable interrupt from AHB DMA Channel #2.
D24	R/W	DMA1	0	Enable interrupt from AHB DMA Channel #1.
D23:13	R/W	Not used	0x000	Always set this field to 0.
D12	R/W	Not used	0	**Always write to 0.**
D11	R/W	1284E	0	Enable interrupt from IEEE-1284 module.
D10	R/W	I2CE	0	Enable interrupt from I2C module.
D09	R/W	SDTXE	0	Enable interrupt from SER transmit module D.
D08	R/W	SDRXE	0	Enable interrupt from SER receive module D.
D07	R/W	SCTXE	0	Enable interrupt from SER transmit module C.
D06	R/W	SCRXE	0	Enable interrupt from SER receive module C.
D05	R/W	SATXE	0	Enable interrupt from SER transmit module A.
D04	R/W	SARXE	0	Enable interrupt from SER receive module A.
D03	R/W	SBTXE	0	Enable interrupt from SER transmit module B.
D02	R/W	SBRXE	0	Enable interrupt from SER receive module B.
D01	R/W	USBE	0	Enable interrupt from USB module.

Table 318: BBus Bridge Interrupt Enable register bit definition

Bits	Access	Mnemonic	Reset	Description
D00	R/W	DMAE	0	Enable aggregate interrupt from BBus DMA module. These interrupts can be controlled on a per-DMA channel basis in the BBus utility module.

Table 318: BBus Bridge Interrupt Enable register bit definition

CHAPTER 9

The NS9775 ASIC BBus *subsystem* contains two DMA controllers, each with 16 channels.

Note: These DMA controllers are different than the AHB DMA controllers discussed in the BBus Bridge chapter.

About the BBus DMA controllers

There are two BBus DMA controllers. One DMA controller supports all BBus peripherals except the USB device; the other DMA controller is dedicated to the USB device interface (see the USB Controller Module chapter for more information). Each DMA controller contains 16 channels, and each DMA channel moves data between external memory and internal peripherals in fly-by mode, minimizing CPU intervention.

Figure 85 shows the data flow for fly-by DMA transfers.

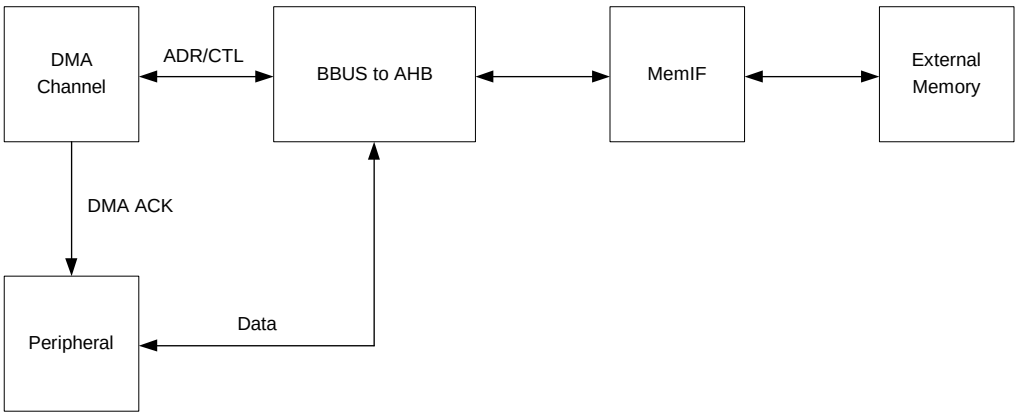


Figure 85: DMA fly-by transfers

Note: Neither memory-to-memory transfers nor DMA transfers to external peripherals are supported.

Each DMA controller has a state machine and a block of static RAM, referred to as *context* RAM.

- The context RAM contains the current state of each DMA channel.
- The single state machine supports all DMA channels in parallel, by context-switching from channel to channel.

Figure 86 shows the BBus DMA controller block.

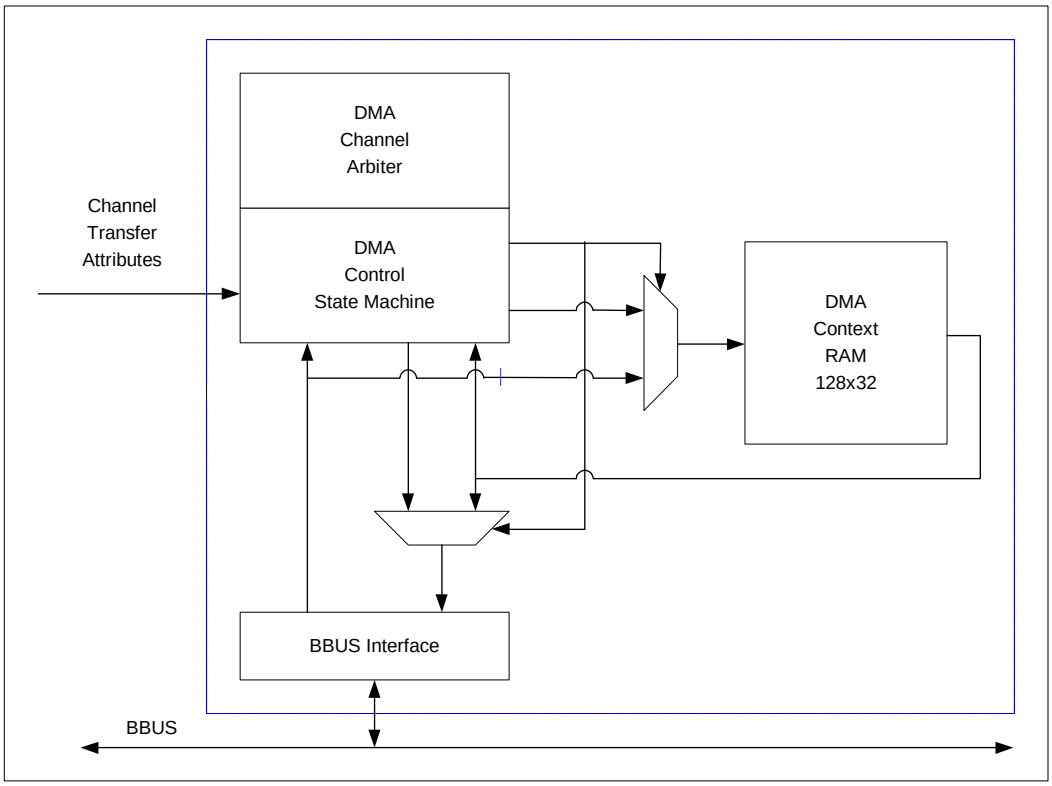


Figure 86: DMA controller block

Each DMA controller arbiter determines in which channel the state machine currently is operating.

DMA context memory

Each DMA controller maintains state for all 16 channels using an on-chip SRAM known as the *context memory*. One 128x32 single port SRAM macrocell comprises this memory. Table 319 defines the entries that describe the state of each DMA channel.

Offset	Description
0x00	Buffer descriptor pointer
0x01	Control register
0x02	Status register
0x03	Unused
0x04	Source Address register
0x05	Buffer Length register
0x06	Destination Address register
0x07	Control flags and transfer status

Table 319: DMA context memory entry

DMA buffer descriptor

All DMA channels operate using a buffer descriptor. Each DMA channel remains idle until enabled through the DMA Channel Control register. When a DMA channel is activated, it reads the DMA buffer descriptor pointed to by the Buffer Descriptor Pointer register. When the current descriptor is retired, the next descriptor is accessed from a circular buffer.

Each DMA buffer descriptor is four 32-bit words in length. Multiple buffer descriptors are located in circular buffers of 1024 bytes, with a maximum of 64 buffer descriptors. The DMA channel's buffer descriptor pointer provides the first buffer descriptor address. Subsequent buffer descriptors are found adjacent to the first descriptor. The final buffer descriptor is defined with its *W* bit set. When the DMA channel encounters the W bit, the channel wraps around to the first descriptor.

Note: Configuring a DMA channel for more than the maximum number of buffer descriptors results in unpredictable behavior.

Figure 87 shows the DMA buffer descriptor. Table 320 explains each buffer descriptor component.

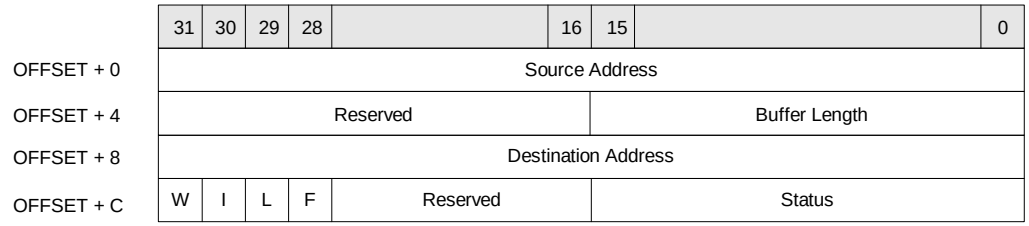


Figure 87: DMA buffer descriptor

Field	Description
Source address	Identifies the starting location of the source data buffer. ■ For **transmit** buffers. The source address can start on any byte boundary. ■ For **receive** buffers. The source address must be word-aligned. Be sure the source address field points to an existing memory location.
Buffer length	■ Indicates, in *fly-by peripheral-to-memory operations*, the maximum number of bytes available in the receive buffer pointed to by the source buffer pointer. After filling a receive buffer with peripheral data, the DMA controller updates this field with the initial buffer length less the actual receive data byte count. **Note:** The buffer length must be a multiple of four bytes. ■ Indicates, in *fly-by memory-to-peripheral operations*, the number of bytes to move from the source address pointer to the peripheral device. After completing a transmit buffer descriptor, the DMA controller updates this field with the initial buffer length less the actual transmit data byte count (useful for error conditions). In either mode, this field is limited to 16 bits, which supports a maximum transfer size of 65535 bytes.
Destination address	**This field is not used in BBus DMA transfers.** The field is updated with all zeroes when the descriptor is retired.

Table 320: DMA buffer descriptor definition

Field	Description
W	The **wrap** bit. When set, this bit informs the DMA controller that this is the last buffer descriptor within the continuous list of descriptors for the channel. The next buffer descriptor is found using the initial DMA channel buffer descriptor pointer. When the WRAP bit is not set, the next buffer descriptor is found using a 16 byte offset from the current buffer descriptor.
I	The **interrupt** bit. When set, this bit tells the DMA controller to issue an interrupt to the CPU when the buffer is closed due to a normal channel completion. The interrupt occurs no matter what the normal completion interrupt enable configuration is for the DMA channel.
L	The **last** bit. This bit indicates end-of-packet status. ■ In fly-by peripheral-to-memory operations, this bit indicates that the buffer was closed due to an end-of-packet status signal from the peripheral to the DMA controller. ■ In fly-by memory-to-peripheral operations, this bit indicates to the DMA controller that this buffer descriptor marks the end of the packet. **Note:** For USB-IN transactions (DMA read), this bit must always be set to 1.
F	The **full** bit. When set, this bit indicates that the buffer is full. A DMA channel sets this bit after filling a buffer. A DMA channel clears this bit after emptying a buffer. A DMA channel does not try to empty a buffer with the F bit clear. Similarly, a DMA channel does not try to fill a buffer with the F bit set. When firmware modifies the F bit, the firmware also must write a 1 to the CE bit in the DMA Channel Control register to activate the idle channel.
Reserved	You must write a 0 to this field.
Status	16-bit status field. The USB and serial controllers use this field to store transmit and receive status words that result from a completed transmit or receive data frame. **Be advised:** The BBus DMA buffer descriptor status field may not reflect the occurrence of a receive overrun in the serial module.

Table 320: DMA buffer descriptor definition

DMA transfer status

The DMA buffer descriptor status field is updated when the buffer descriptor is retired. Tables 321 through 326 provide a brief description of the 16-bit status fields for each peripheral. See the appropriate chapters in this manual for more information about each bit.

Bits	Mnemonic	Description
15	MATCH1	Receive character match #1
14	MATCH2	Receive character match #2
13	MATCH3	Receive character match #3
12	MATCH4	Receive character match #4
11	BGAP	Buffer gap timeout
10	CGAP	Character gap timeout
09:04	UNUSED	Not used — read back 0
03	RBRK	Receive line break
02	RFE	Receive frame error
01	RPE	Receive parity error
00	ROVER	Receive overrun error

Table 321: Peripheral bit fields: Serial controller — UART RX mode

Bits	Mnemonic	Description
15	MATCH1	Receive character match #1
14	MATCH2	Receive character match #2
13	MATCH3	Receive character match #3
12	MATCH4	Receive character match #4
11:00	UNUSED	Not used — read back 0

Table 322: Peripheral bit fields: Serial controller — SPI RX mode

Bits	Mnemonic	Description
15:00	UNUSED	Not used — read back 0

Table 323: Peripheral bit fields: Serial controller — UART TX mode

Bits	Mnemonic	Description
15:00	UNUSED	Not used — read back 0

Table 324: Peripheral bit fields: Serial controller — SPI TX mode

Bits	Mnemonic	Description
15:14	STATE	00 Undefined 01 Data phase transaction 10 Status phase transaction 11 No-data status phase transaction Defines the state of the endpoint after the most recent communication with the USB device module. This field is used primarily for debugging.
13	M31	See the USB Controller module chapter.
12	M30	See the USB Controller module chapter.
11:00	CIA	**If field M30 equals 1,** this field contains the least significant 12 bits of the Setup command address. Because all Setup command addresses are required to be in the format ???, where ??? is not equal to 000, the most significant nibble is zero. **If the M30 field equals 0,** this field contains the configuration, interface, and alternate information for the specified endpoint.

Table 325: Peripheral bit fields: USB device controller

Bits	Mnemonic	Description
15:00	UNUSED	Not used — read back 0

Table 326: Peripheral bit fields: IEEE 1284 controller

DMA channel assignments

Each BBus DMA controller contains 16 DMA channels. Controller DMA1 is dedicated to the BBus peripherals. Controller DMA2 is dedicated to the USB device endpoints. Any given DMA channel is hard-wired to a peripheral.

Table 327 indicates which peripherals are hard-wired to which DMA channels, and the DMA mode (direction) required for each. These are the DMA modes:

- FBR — Fly-by memory-to-peripheral
- FBW — Fly-by peripheral-to-memory
- FBRW — Fly-by programmable for either direction

DMA	Channel	DMA channel peripheral	Fly-by direction
DMA1	1	SER channel B receiver	FBW
DMA1	2	SER channel B transmitter	FBR
DMA1	3	SER channel A receiver	FBW
DMA1	4	SER channel A transmitter	FBR
DMA1	5	SER channel C receiver	FBW
DMA1	6	SER channel C transmitter	FBR
DMA1	7	SER channel D receiver	FBW
DMA1	8	SER channel D transmitter	FBR
DMA1	9	1284 command receiver	FBW
DMA1	10	Unused	N/A

Table 327: DMA channel assignments

DMA	Channel	DMA channel peripheral	Fly-by direction
DMA1	11	1284 data receiver	FBW
DMA1	12	1284 data transmitter	FBR
DMA1	13	Unused	N/A
DMA1	14	Unused	N/A
DMA1	15	Unused	N/A
DMA1	16	Unused	N/A
DMA2	1	USB device control-OUT endpoint #0	FBW
DMA2	2	USB device control-IN endpoint #0	FBR
DMA2	3	USB device endpoint#1	FBRW
DMA2	4	USB device endpoint#2	FBRW
DMA2	5	USB device endpoint#3	FBRW
DMA2	6	USB device endpoint#4	FBRW
DMA2	7	USB device endpoint#5	FBRW
DMA2	8	USB device endpoint#6	FBRW
DMA2	9	USB device endpoint#7	FBRW
DMA2	10	USB device endpoint#8	FBRW
DMA2	11	USB device endpoint#9	FBRW
DMA2	12	USB device endpoint#10	FBRW
DMA2	13	USB device endpoint#11	FBRW
DMA2	14	Unused	N/A
DMA2	15	Unused	N/A
DMA2	16	Unused	N/A

Table 327: DMA channel assignments

DMA Control and Status registers

The configuration registers for DMA1 are located at 0x9000 0000. The configuration registers for DMA2 are located at 0x9011 0000. All configuration registers must be accessed as 32-bit words and as single accesses only. No bursting is allowed.

Table 328 is a single DMA controller address map.

Important: Be aware that the registers listed in this table are not discrete registers; they are combined with other information and stored in the context SRAM within each DMA module. The offsets allow address bits [08:05] to encode the DMA channel number.

Offset	Description
9000 0000 / 9011 0000	DMA Channel 1 Buffer Descriptor Pointer
9000 0020 / 9011 0020	DMA Channel 2 Buffer Descriptor Pointer
9000 0040 / 9011 0040	DMA Channel 3 Buffer Descriptor Pointer
9000 0060 / 9011 0060	DMA Channel 4 Buffer Descriptor Pointer
9000 0080 / 9011 0080	DMA Channel 5 Buffer Descriptor Pointer
9000 00A0 / 9011 00A0	DMA Channel 6 Buffer Descriptor Pointer
9000 00C0 / 9011 00C0	DMA Channel 7 Buffer Descriptor Pointer
9000 00E0 / 9011 00E0	DMA Channel 8 Buffer Descriptor Pointer
9000 0100 / 9011 0100	DMA Channel 9 Buffer Descriptor Pointer
9000 0120 / 9011 0120	DMA Channel 10 Buffer Descriptor Pointer
9000 0140 / 9011 0140	DMA Channel 11 Buffer Descriptor Pointer
9000 0160 / 9011 0160	DMA Channel 12 Buffer Descriptor Pointer
9000 0180 / 9011 0180	DMA Channel 13 Buffer Descriptor Pointer
9000 01A0 / 9011 01A0	DMA Channel 14 Buffer Descriptor Pointer
9000 01C0 / 9011 01C0	DMA Channel 15 Buffer Descriptor Pointer
9000 01E0 / 9011 01E0	DMA Channel 16 Buffer Descriptor Pointer
9000 0010 / 9011 0010	DMA Channel 1 Control register

Table 328: DMA Control and Status register address map

Offset	Description
9000 0030 / 9011 0030	DMA Channel 2 Control register
9000 0050 / 9011 0050	DMA Channel 3 Control register
9000 0070 / 9011 0070	DMA Channel 4 Control register
9000 0090 / 9011 0090	DMA Channel 5 Control register
9000 00B0 / 9011 00B0	DMA Channel 6 Control register
9000 00D0 / 9011 00D0	DMA Channel 7 Control register
9000 00F0 / 9011 00F0	DMA Channel 8 Control register
9000 0110 / 9011 0110	DMA Channel 9 Control register
9000 0130 / 9011 0130	DMA Channel 10 Control register
9000 0150 / 9011 0150	DMA Channel 11 Control register
9000 0170 / 9011 0170	DMA Channel 12 Control register
9000 0190 / 9011 0190	DMA Channel 13 Control register
9000 01B0 / 9011 01B0	DMA Channel 14 Control register
9000 01D0 / 9011 01D0	DMA Channel 15 Control register
9000 01F0 / 9011 01F0	DMA Channel 16 Control register
9000 0014 / 9011 0014	DMA Channel 1 Status/Interrupt Enable register
9000 0034 / 9011 0034	DMA Channel 2 Status/Interrupt Enable register
9000 0054 / 9011 0054	DMA Channel 3 Status/Interrupt Enable register
9000 0074 / 9011 0074	DMA Channel 4 Status/Interrupt Enable register
9000 0094 / 9011 0094	DMA Channel 5 Status/Interrupt Enable register
9000 00B4 / 9011 00B4	DMA Channel 6 Status/Interrupt Enable register
9000 00D4 / 9011 00D4	DMA Channel 7 Status/Interrupt Enable register
9000 00F4 / 9011 00F4	DMA Channel 8 Status/Interrupt Enable register
9000 0114 / 9011 0114	DMA Channel 9 Status/Interrupt Enable register
9000 0134 / 9011 0134	DMA Channel 10 Status/Interrupt Enable register
9000 0154 / 9011 0154	DMA Channel 11 Status/Interrupt Enable register
9000 0174 / 9011 0174	DMA Channel 12 Status/Interrupt Enable register

Table 328: DMA Control and Status register address map

Offset	Description
9000 0194 / 9011 0194	DMA Channel 13 Status/Interrupt Enable register
9000 01B4 / 9011 01B4	DMA Channel 14 Status/Interrupt Enable register
9000 01D4 / 9011 01D4	DMA Channel 15 Status/Interrupt Enable register
9000 01F4 / 9011 01F4	DMA Channel 16 Status/Interrupt Enable register

Table 328: DMA Control and Status register address map

DMA Buffer Descriptor Pointer

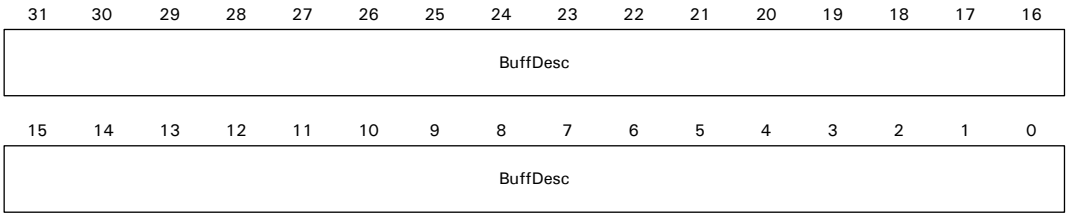
Address: DMA1

9000 0000 / 0020 / 0040 / 0060 / 0080 / 00A0 / 00C0 / 00E0 / 0100 / 0120 / 0140 / 0160 / 0180 / 01A0 / 01C0 / 01E0

Address: DMA2

9011 0000 / 0020 / 0040 / 0060 / 0080 / 00A0 / 00C0 / 00E0 / 0100 / 0120 / 0140 / 0160 / 0180 / 01A0 / 01C0 / 01E0

The DMA Buffer Descriptor Pointer register contains a 32-bit pointer to the first buffer descriptor in a contiguous list of buffer descriptors. There is one Buffer Descriptor Pointer for each channel within each DMA controller module. Each buffer descriptor is 16 bytes in length.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:00	R/W	BuffDesc	0x00000000	**Buffer descriptor** 32-bit pointer to a buffer descriptor.

Table 329: BBus DMA Buffer Descriptor Pointer register bit definition

DMA Control register

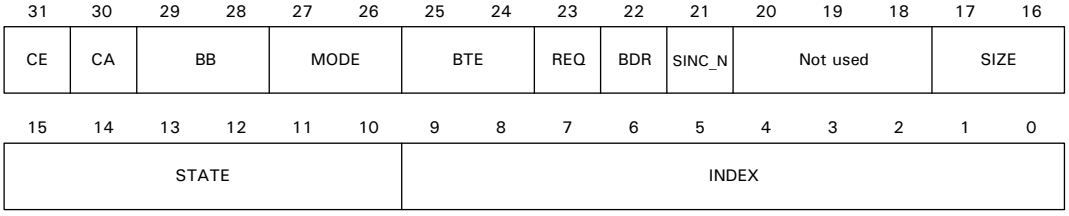
Address: DMA1

9000 0010 / 0030 / 0050 / 0070 / 0090 / 00B0 / 00D0 / 00F0 / 0110 / 0130 / 0150 / 0170 / 0190 / 01B0 / 01D0 / 01F0

Address: DMA2

9011 0010 / 0030 / 0050 / 0070 / 0090 / 00B0 / 00D0 / 00F0 / 0110 / 0130 / 0150 / 0170 / 0190 / 01B0 / 01D0 / 01F0

The DMA Control register contains required transfer control information. There is a DMA Control register for each channel within each DMA controller module.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31	R/W	CE	0	**Channel enable** 0 Disables DMA operations 1 Enables DMA operations Enables and disables DMA operations, as wanted.
D30	R/W	CA	0	**Channel abort** When set, causes the current DMA operation to complete and closes the buffer.
D29:28	R/W	BB	0	**Bus bandwidth** Always set to 0.

Table 330: BBus DMA Control register bit definition

Bits	Access	Mnemonic	Reset	Description
D27:26	R/W	MODE	0	**Fly-by mode** 00 Fly-by write (peripheral-to-memory) 01 Fly-by read (memory-to-peripheral) 10 Undefined 11 Undefined Defines the fly-by transfer mode.
D25:24	R/W	BTE	0	**Burst transfer enable** 00 1 operand 01 2 operands 10 4 operands (**Recommended**) 11 Reserved Determines whether the DMA channel can use burst transfers through the bus. This configuration applies to both buffer descriptor and peripheral data access.
D23	R/W	REQ	0	Always set to 0.
D22	R/W	BDR	0	**Buffer descriptor refetch** Causes the DMA controller to refetch the current buffer descriptor before proceeding. This is necessary to retransmit erroneous packets sent from the USB device to the USB host. Hardware automatically clears this field after refetching the buffer descriptor.
D21	R/W	SINC_N	0	**Source address increment field** 0 Increment source address pointer 1 Do not increment source address pointer Controls whether the source address pointers are incremented after each DMA transfer. The DMA controller uses this field in all modes whenever referring to a memory address.
D20:18	R/W	Not used	0	N/A
D17:16	R/W	SIZE	0	**Size field** Must always be set to 0. The datapath between the BBus and AHB bus is 32 bits. If the system memory bus is less than 32 bits, the translation is handled in the memory controller.

Table 330: BBus DMA Control register bit definition

Bits	Access	Mnemonic	Reset	Description
D15:10	R	STATE	0	**State field** 0x00 Idle 0x20 Transfer in progress 0x18 Update buffer descriptor Describes the current state of the DMA controller state machine.
D09:00	R	INDEX	0	**Index value** Identifies the current byte offset pointer relative to the buffer descriptor pointer.

Table 330: BBus DMA Control register bit definition

DMA Status/Interrupt Enable register

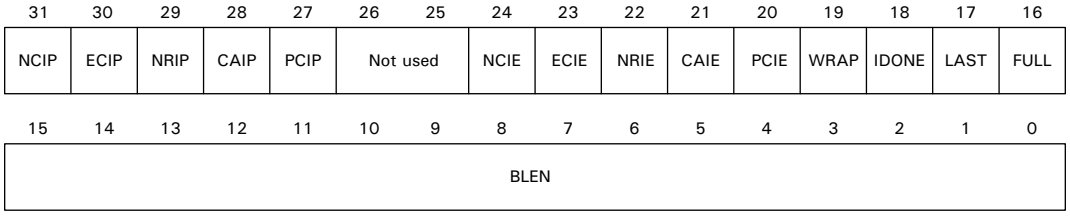
Address: DMA1

9000 0014 / 0034 / 0054 / 0074 / 0094 / 00B4 / 00D4 / 00F4 / 0114 / 0134 / 0154 / 0174 / 0194 / 01B4 / 01D4 / 01F4

Address: DMA2

9011 0014 / 0034 / 0054 / 0074 / 0094 / 00B4 / 00D4 / 00F4 / 0114 / 0134 / 0154 / 0174 / 0194 / 01B4 / 01D4 / 01F4

The DMA Status/Interrupt Enable register contains DMA transfer status as well as control information for generating interrupt signals. There is a DMA Status/Interrupt Enable register for each channel within each DMA controller module.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31	RW1TC	NCIP	0	**Normal completion interrupt pending** Set when a buffer descriptor is closed (for normal conditions). An interrupt is generated when either the NCIE (D24) bit is set or the IDONE (D18) bit is found active in the current buffer descriptor. A normal DMA channel completion occurs when the BLEN count (15:00) expires to 0 or when a peripheral device signals completion.
D30	RW1TC	ECIP	0	**Error completion interrupt pending** Set when the DMA channel encounters either a bad buffer descriptor pointer or a bad data buffer pointer. An interrupt is generated if the ECIE (D23) bit is set. The DMA channel stops until the CE bit (in the DMA Channel Control register) is written to a 1 by firmware. The DMA channel does not advance to the next buffer descriptor. When ECIP Is cleared by firmware, the buffer descriptor is tried again from where it left off. The CA bit in the appropriate DMA Channel Control register can be used to abort the current buffer descriptor and advance to the next buffer.
D29	RW1TC	NRIP	0	**Buffer not ready interrupt pending** Set when the DMA channel finds a buffer descriptor whose F bit is in the incorrect state. An interrupt is generated if the NRIE (D22) bit is set. When NRIP is set, the DMA channel stops until firmware writes a 1 to the CE field (in the DMA Channel Control register). The DMA channel does not advance to the next buffer descriptor.

Table 331: DMA Status/Interrupt Enable register bit definition

Bits	Access	Mnemonic	Reset	Description
D28	RW1TC	CAIP	0	**Channel abort interrupt pending** Set when the DMA channel finds the CA bit set in the DMA Channel Control register. An interrupt is generated when the CAIE (D21) bit is set. When CAIP Is set, the DMA channel retires the current buffer descriptor and stops until firmware writes a 1 to the CE bit (in the appropriate DMA Channel Control register). **Note:** The CA bit must be cleared, using firmware, before the CE field is written. Failure to reset the CA bit causes the subsequent buffer descriptor to abort.
D27	R/W	PCIP	0	**Premature complete interrupt pending** Set when the DMA channel, configured for fly-by write mode, receives an end-of-transfer indicator from the peripheral while processing a DMA buffer descriptor. An interrupt is generated if the PCIE (D20) bit is set. The DMA channel continues processing buffer descriptors. NCIP is set when PCIP is set, for backward compatibility.
D26:25	R/W	Unused	0	Always set to 0.
D24	R/W	NCIE	0	Enable NCIP interrupt generation.
D23	R/W	ECIE	0	Enable ECIP interrupt generation. This bit always should be enabled during normal operation.
D22	R/W	NRIE	0	Enable NRIP interrupt generation.
D21	R/W	CAIE	0	Enable CAIP interrupt generation. This bit always should be enabled during normal operation.
D20	R/W	PCIE	0	Enable PCIP interrupt generation.
D19	R	WRAP	0	Debug field, indicating the last descriptor in the descriptor list.
D18	R	IDONE	0	Debug field, indicating interrupt on done.
D17	R	LAST	0	Debug field, indicating the last buffer descriptor in the current data frame.
D16	R	FULL	0	Debug field, indicating the buffer is full.

Table 331: DMA Status/Interrupt Enable register bit definition

Bits	Access	Mnemonic	Reset	Description
D15:00	R	BLEN	0x000	Debug field, indicating the remaining byte transfer count.

Table 331: DMA Status/Interrupt Enable register bit definition

BBus Utility

CHAPTER 10

The BBus utility provides chip-level support for the low speed peripherals in the NS9775 ASIC that reside on the Digi proprietary BBus. The BBus utility handles functions such as bus monitors, GPIO control, and peripheral reset.

BBus Utility Control and Status registers

The BBus Utility configuration registers are located at base address 0x9060 0000. Table 332 lists the control and status registers in the BBus Utility.

All configuration registers must be accessed as 32-bit words and as single accesses only. No bursting is allowed.

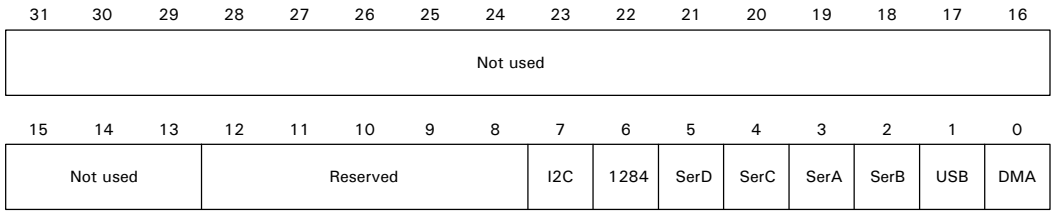
Address	Description
9060 0000	Master Reset register
9060 0004	Reserved (Do not write to this address)
9060 0010	GPIO Configuration Register #1
9060 0014	GPIO Configuration Register #2
9060 0018	GPIO Configuration Register #3
9060 001C	GPIO Configuration Register #4
9060 0020	GPIO Configuration Register #5
9060 0024	GPIO Configuration Register #6
9060 0028	GPIO Configuration Register #7
9060 0030	GPIO Control Register #1
9060 0034	GPIO Control Register #2
9060 0040	GPIO Status Register #1
9060 0044	GPIO Status Register #2
9060 0050	BBus Monitor register
9060 0060	BBus DMA Interrupt Status register
9060 0064	BBus DMA Interrupt Enable register
9060 0070	USB Configuration register
9060 0080	Endian Configuration register
9060 0090	ARM Wake-up register

Table 332: BBus Utility configuration and status register address map

Master Reset register

Address: 9060 0000

The Master Reset register contains the reset control signals for all BBus peripherals. All BBus peripherals, except the bridge, are held in reset after power-on reset is deasserted. All reset bits in this register are active high.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:13	R	Not used	0x0	Always read as 0x0.
D12:08	N/A	Reserved	N/A	N/A
D07	R/W	I^2C	1	I^2C Controller reset
D06	R/W	1284	1	IEEE 1284 Controller reset
D05	R/W	SerD	1	Serial Controller port D reset
D04	R/W	SerC	1	Serial Controller port C reset
D03	R/W	SerA	1	Serial Controller port A reset
D02	R/W	SerB	1	Serial Controller port B reset
D01	R/W	USB	1	USB Controller reset
D00	R/W	DMA	1	BBus DMA reset

Table 333: Master Reset register

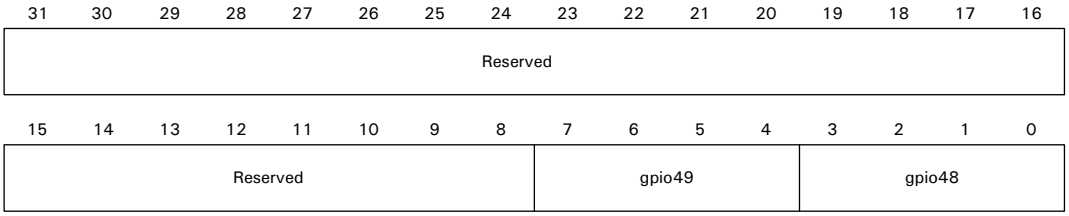
GPIO Configuration registers

GPIO Configuration registers #1 – #7 contain the configuration information for each of the 50 GPIO pins in the NS9775. Each GPIO pin is defined to have up to four functions.

Configure each pin for the appropriate function and direction, as shown in Table 341: "GPIO Configuration register options" on page 540.

GPIO Configuration Register #7

Address: 9060 0028

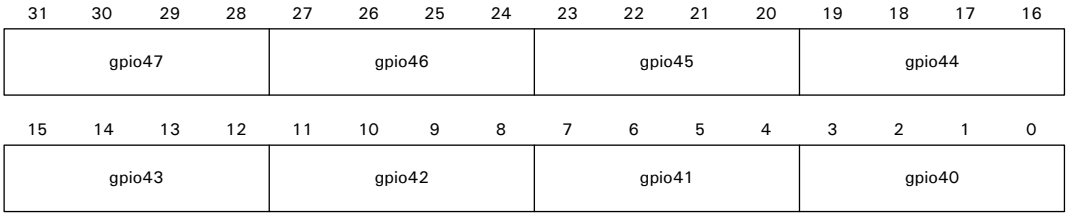


Bits	Access	Mnemonic	Reset	Description
D31:08	N/A	Reserved	N/A	N/A
D07:04	R/W	gpio49	0x3	gpio[49] configuration
D03:00	R/W	gpio48	0x3	gpio[48] configuration

Table 334: GPIO Configuration Register #7

GPIO Configuration Register #6

Address: 9060 0024

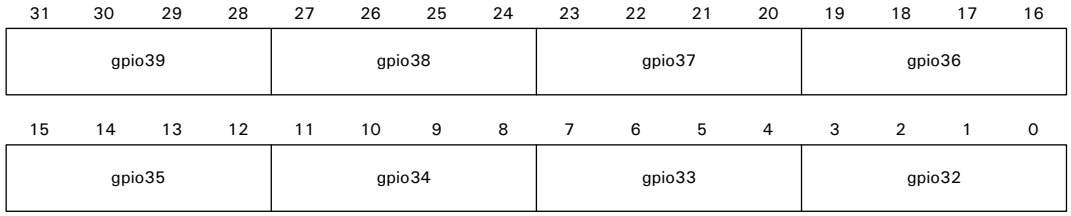


Bits	Access	Mnemonic	Reset	Description
D31:28	R/W	gpio47	0x3	gpio[47] configuration
D27:24	R/W	gpio46	0x3	gpio[46] configuration
D23:20	R/W	gpio45	0x3	gpio[45] configuration
D19:16	R/W	gpio44	0x3	gpio[44] configuration
D15:12	R/W	gpio43	0x3	gpio[43] configuration
D11:08	R/W	gpio42	0x3	gpio[42] configuration
D07:04	R/W	gpio41	0x3	gpio[41] configuration
D03:00	R/W	gpio40	0x3	gpio[40] configuration

Table 335: GPIO Configuration Register #6

GPIO Configuration Register #5

Address: 9060 0020

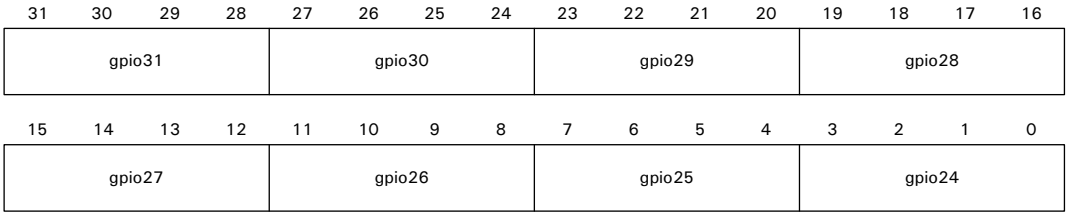


Bits	Access	Mnemonic	Reset	Description
D31:28	R/W	gpio39	0x3	gpio[39] configuration
D27:24	R/W	gpio38	0x3	gpio[38] configuration
D23:20	R/W	gpio37	0x3	gpio[37] configuration
D19:16	R/W	gpio36	0x3	gpio[36] configuration
D15:12	R/W	gpio35	0x3	gpio[35] configuration
D11:08	R/W	gpio34	0x3	gpio[34] configuration
D07:04	R/W	gpio33	0x3	gpio[33] configuration
D03:00	R/W	gpio32	0x3	gpio[32] configuration

Table 336: GPIO Configuration Register #5

GPIO Configuration Register #4

Address: 9060 001C

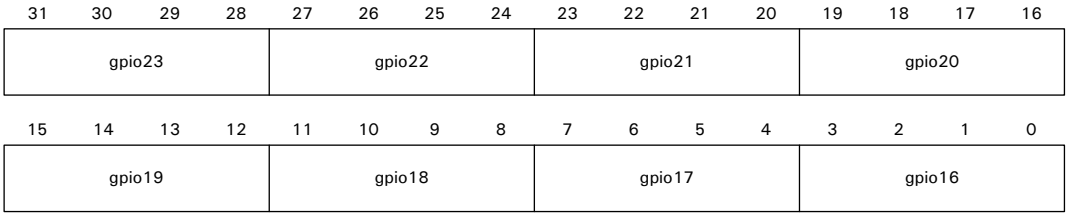


Bits	Access	Mnemonic	Reset	Description
D31:28	R/W	gpio31	0x3	gpio[31] configuration
D27:24	R/W	gpio30	0x3	gpio[30] configuration
D23:20	R/W	gpio29	0x3	gpio[29] configuration
D19:16	R/W	gpio28	0x3	gpio[28] configuration
D15:12	R/W	gpio27	0x3	gpio[27] configuration
D11:08	R/W	gpio26	0x3	gpio[26] configuration
D07:04	R/W	gpio25	0x3	gpio[25] configuration
D03:00	R/W	gpio24	0x3	gpio[24] configuration

Table 337: GPIO Configuration Register #4

GPIO Configuration Register #3

Address: 9060 0018

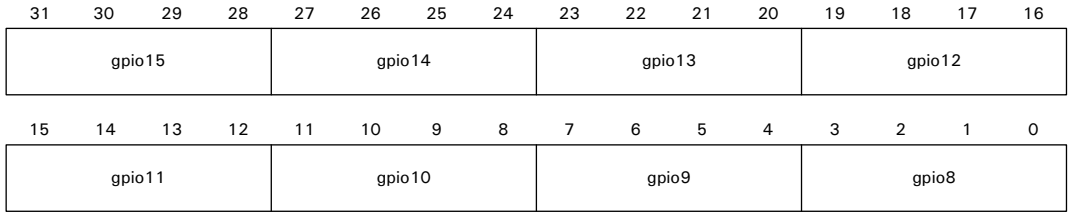


Bits	Access	Mnemonic	Reset	Description
D31:28	R/W	gpio23	0x3	gpio[23] configuration
D27:24	R/W	gpio22	0x3	gpio[22] configuration
D23:20	R/W	gpio21	0x3	gpio[21] configuration
D19:16	R/W	gpio20	0x3	gpio[20] configuration
D15:12	R/W	gpio19	0x3	gpio[19] configuration
D11:08	R/W	gpio18	0x3	gpio[18] configuration
D07:04	R/W	gpio17	0x3	gpio[17] configuration
D03:00	R/W	gpio16	0x3	gpio[16] configuration

Table 338: GPIO Configuration register #3

GPIO Configuration Register #2

Address: 9060 0014

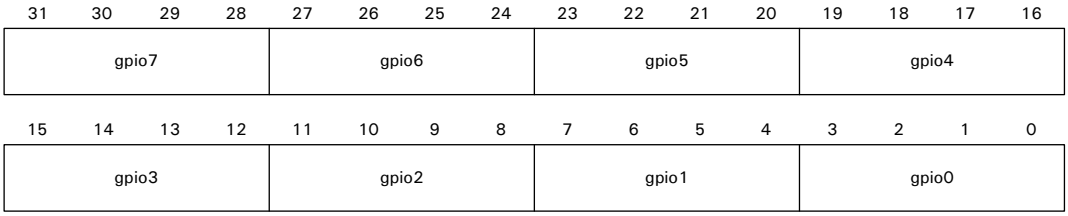


Bits	Access	Mnemonic	Reset	Description
D31:28	R/W	gpio15	0x3	gpio[15] configuration
D27:24	R/W	gpio14	0x3	gpio[14] configuration
D23:20	R/W	gpio13	0x3	gpio[13] configuration
D19:16	R/W	gpio12	0x3	gpio[12] configuration
D15:12	R/W	gpio11	0x3	gpio[11] configuration
D11:08	R/W	gpio10	0x3	gpio[10] configuration
D07:04	R/W	gpio9	0x3	gpio[9] configuration
D03:00	R/W	gpio8	0x3	gpio[8] configuration

Table 339: GPIO Configuration Register #2

GPIO Configuration Register #1

Address: 9060 0010



Bits	Access	Mnemonic	Reset	Description
D31:28	R/W	gpio7	0x3	gpio[7] configuration
D27:24	R/W	gpio6	0x3	gpio[6] configuration
D23:20	R/W	gpio5	0x3	gpio[5] configuration
D19:16	R/W	gpio4	0x3	gpio[4] configuration
D15:12	R/W	gpio3	0x3	gpio[3] configuration
D11:08	R/W	gpio2	0x3	gpio[2] configuration
D07:04	R/W	gpio1	0x3	gpio[1] configuration
D03:00	R/W	gpio0	0x3	gpio[0] configuration

Table 340: GPIO Configuration Register #1

GPIO Configuration register options

Bits	Access	Mnemonic	Description
D03	R/W	PINd	0 Input 1 Output Controls the direction of the GPIO pin. All GPIO pins reset to the input state. In certain modes, the GPIO pin is bidirectional and controlled by the selected peripheral.
D02	N/A	Not used	Must write 0.

Table 341: GPIO Configuration register options

Bits	Access	Mnemonic	Description
D01:00	R/W	PINn	00 Function #0 01 Function #1 10 Function #2 11 Function #3 Use these bits to select the function to use. See the discussion of GPIO MUX for details about the available pin functions.

Table 341: GPIO Configuration register options

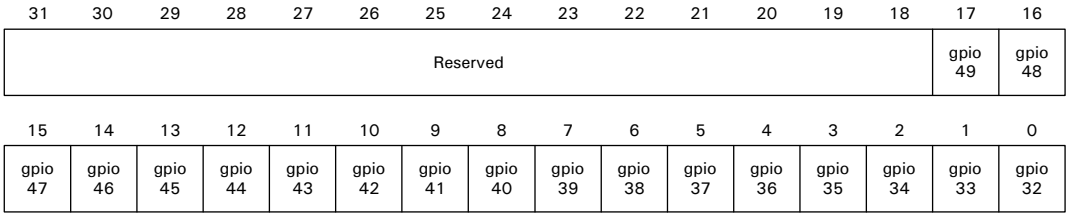
GPIO Control registers

GPIO Control Registers #1 and #2 contain the control information for each of the 50 GPIO pins in the NS9775, as shown in Table 342 and Table 343.

When a GPIO pin is configured as a GPIO output, the corresponding bit in GPIO Control Registers #1 and #2 is driven out the GPIO pin. In all configurations, the CPU has read/write access to the register.

GPIO Control Register#2

Address: 9060 0034



Bits	Access	Mnemonic	Reset	Description
D31:18	N/A	Reserved	N/A	N/A
D17	R/W	gpio49	0	gpio[49] control bit

Table 342: GPIO Control Register #2

Bits	Access	Mnemonic	Reset	Description
D16	R/W	gpio48	0	gpio[48] control bit
D15	R/W	gpio47	0	gpio[47] control bit
D14	R/W	gpio46	0	gpio[46] control bit
D13	R/W	gpio45	0	gpio[45] control bit
D12	R/W	gpio44	0	gpio[44] control bit
D11	R/W	gpio43	0	gpio[43] control bit
D10	R/W	gpio42	0	gpio[42] control bit
D09	R/W	gpio41	0	gpio[41] control bit
D08	R/W	gpio40	0	gpio[40] control bit
D07	R/W	gpio39	0	gpio[39] control bit
D06	R/W	gpio38	0	gpio[38] control bit
D05	R/W	gpio37	0	gpio[37] control bit
D04	R/W	gpio36	0	gpio[36] control bit
D03	R/W	gpio35	0	gpio[35] control bit
D02	R/W	gpio34	0	gpio[34] control bit
D01	R/W	gpio33	0	gpio[33] control bit
D00	R/W	gpio32	0	gpio[32] control bit

Table 342: GPIO Control Register #2

GPIO Control Register #1

Address: 9060 0030

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
gpio 31	gpio 30	gpio 29	gpio 28	gpio 27	gpio 26	gpio 25	gpio 24	gpio 23	gpio 22	gpio 21	gpio 20	gpio 19	gpio 18	gpio 17	gpio 16

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
gpio 15	gpio 14	gpio 13	gpio 12	gpio 11	gpio 10	gpio 9	gpio 8	gpio 7	gpio 6	gpio 5	gpio 4	gpio 3	gpio 2	gpio 1	gpio 0

Bits	Access	Mnemonic	Reset	Description
D31	R/W	gpio31	0	gpio[31] control bit
D30	R/W	gpio30	0	gpio[30] control bit
D29	R/W	gpio29	0	gpio[29] control bit
D28	R/W	gpio28	0	gpio[28] control bit
D27	R/W	gpio27	0	gpio[27] control bit
D26	R/W	gpio26	0	gpio[26] control bit
D25	R/W	gpio25	0	gpio[25] control bit
D24	R/W	gpio24	0	gpio[24] control bit
D23	R/W	gpio23	0	gpio[23] control bit
D22	R/W	gpio22	0	gpio[22] control bit
D21	R/W	gpio21	0	gpio[21] control bit
D20	R/W	gpio20	0	gpio[20] control bit
D19	R/W	gpio19	0	gpio[19] control bit
D18	R/W	gpio18	0	gpio[18] control bit
D17	R/W	gpio17	0	gpio[17] control bit
D16	R/W	gpio16	0	gpio[16] control bit
D15	R/W	gpio15	0	gpio[15] control bit
D14	R/W	gpio14	0	gpio[14] control bit
D13	R/W	gpio13	0	gpio[13] control bit
D12	R/W	gpio12	0	gpio[12] control bit
D11	R/W	gpio11	0	gpio[11] control bit
D10	R/W	gpio10	0	gpio[10] control bit
D09	R/W	gpio9	0	gpio[9] control bit
D08	R/W	gpio8	0	gpio[8] control bit
D07	R/W	gpio7	0	gpio[7] control bit
D06	R/W	gpio6	0	gpio[6] control bit

Table 343: GPIO Control Register #1

Bits	Access	Mnemonic	Reset	Description
D05	R/W	gpio5	0	gpio[5] control bit
D04	R/W	gpio4	0	gpio[4] control bit
D03	R/W	gpio3	0	gpio[3] control bit
D02	R/W	gpio2	0	gpio[2] control bit
D01	R/W	gpio1	0	gpio[1] control bit
D00	R/W	gpio0	0	gpio[0] control bit

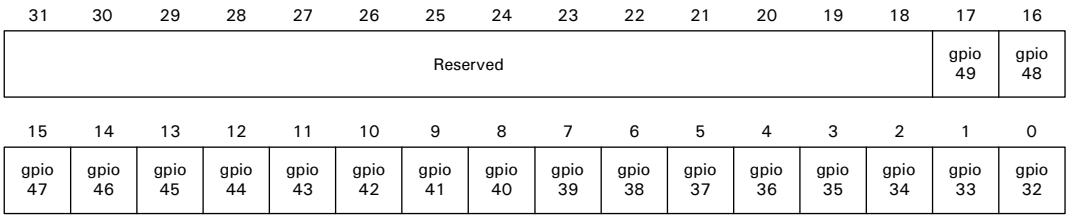
Table 343: GPIO Control Register #1

GPIO Status registers

GPIO Status Registers #1 and #2 contain the status information for each of the 50 GPIO pins in the NS9775, as shown in Table 344 and Table 345. In all configurations, the value on the GPIO input pin is brought to the Status register and the CPU has *read-only* access to the register.

GPIO Status Register #2

Address: 9060 0044



Note: The reset values for all of the status bits are undefined because they depend on the state of the GPIO pins to NS9775.

Bits	Access	Mnemonic	Reset	Description
D31:18	R	Not used	0x0	Always read as 0x0
D17	R	gpio49	undefined	gpio[49] status bit

Table 344: GPIO Status Register #2

Bits	Access	Mnemonic	Reset	Description
D16	R	gpio48	undefined	gpio[48] status bit
D15	R	gpio47	undefined	gpio[47] status bit
D14	R	gpio46	undefined	gpio[46] status bit
D13	R	gpio45	undefined	gpio[45] status bit
D12	R	gpio44	undefined	gpio[44] status bit
D11	R	gpio43	undefined	gpio[43] status bit
D10	R	gpio42	undefined	gpio[42] status bit
D09	R	gpio41	undefined	gpio[41] status bit
D08	R	gpio40	undefined	gpio[40] status bit
D07	R	gpio39	undefined	gpio[39] status bit
D06	R	gpio38	undefined	gpio[38] status bit
D05	R	gpio37	undefined	gpio[37] status bit
D04	R	gpio36	undefined	gpio[36] status bit
D03	R	gpio35	undefined	gpio[35] status bit
D02	R	gpio34	undefined	gpio[34] status bit
D01	R	gpio33	undefined	gpio[33] status bit
D00	R	gpio32	undefined	gpio[32] status bit

Table 344: GPIO Status Register #2

GPIO Status Register #1

Address: 9060 0040

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
gpio 31	gpio 30	gpio 29	gpio 28	gpio 27	gpio 26	gpio 25	gpio 24	gpio 23	gpio 22	gpio 21	gpio 20	gpio 19	gpio 18	gpio 17	gpio 16

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
gpio 15	gpio 14	gpio 13	gpio 12	gpio 11	gpio 10	gpio 9	gpio 8	gpio 7	gpio 6	gpio 5	gpio 4	gpio 3	gpio 2	gpio 1	gpio 0

Note: The reset values for all of the status bits are undefined because they depend on the state of the GPIO pins to NS9775.

Bits	Access	Mnemonic	Reset	Description
D31	R	gpio31	undefined	gpio[31] status bit
D30	R	gpio30	undefined	gpio[30] status bit
D29	R	gpio29	undefined	gpio[29] status bit
D28	R	gpio28	undefined	gpio[28] status bit
D27	R	gpio27	undefined	gpio[27] status bit
D26	R	gpio26	undefined	gpio[26] status bit
D25	R	gpio25	undefined	gpio[25] status bit
D24	R	gpio24	undefined	gpio[24] status bit
D23	R	gpio23	undefined	gpio[23] status bit
D22	R	gpio22	undefined	gpio[22] status bit
D21	R	gpio21	undefined	gpio[21] status bit
D20	R	gpio20	undefined	gpio[20] status bit
D19	R	gpio19	undefined	gpio[19] status bit
D18	R	gpio18	undefined	gpio[18] status bit
D17	R	gpio17	undefined	gpio[17] status bit
D16	R	gpio16	undefined	gpio[16] status bit
D15	R	gpio15	undefined	gpio[15] status bit
D14	R	gpio14	undefined	gpio[14] status bit
D13	R	gpio13	undefined	gpio[13] status bit
D12	R	gpio12	undefined	gpio[12] status bit
D11	R	gpio11	undefined	gpio[11] status bit
D10	R	gpio10	undefined	gpio[10] status bit
D09	R	gpio9	undefined	gpio[9] status bit
D08	R	gpio8	undefined	gpio[8] status bit
D07	R	gpio7	undefined	gpio[7] status bit

Table 345: GPIO Status Register #1

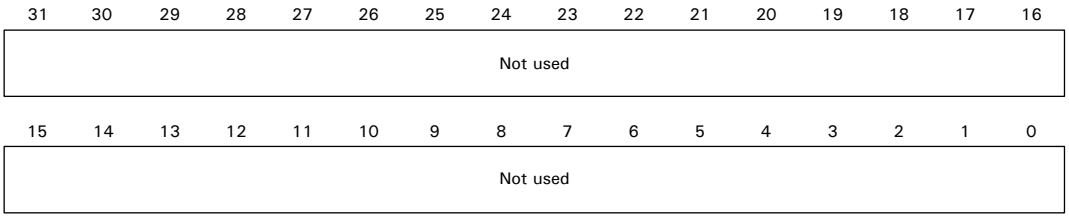
Bits	Access	Mnemonic	Reset	Description
D06	R	gpio6	undefined	gpio[6] status bit
D05	R	gpio5	undefined	gpio[5] status bit
D04	R	gpio4	undefined	gpio[4] status bit
D03	R	gpio3	undefined	gpio[3] status bit
D02	R	gpio2	undefined	gpio[2] status bit
D01	R	gpio1	undefined	gpio[1] status bit
D00	R	gpio0	undefined	gpio[0] status bit

Table 345: GPIO Status Register #1

BBus Monitor register

Address: 9060 0050

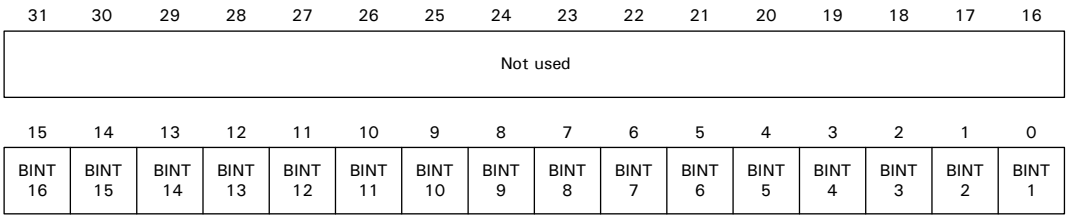
Write 0 to this register.



BBus DMA Interrupt Status register

Address: 9060 0060

The BBus DMA Interrupt Status register contains the interrupt status bits for the BBus DMA Controller. The interrupt bits are active high. Service these interrupts in the BBus DMA controller.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:16	R	Not used	0x0	Always read as 0x0
D15	R	BINT16	0	BBus DMA channel #16 interrupt status
D14	R	BINT15	0	BBus DMA channel #15 interrupt status
D13	R	BINT14	0	BBus DMA channel #14 interrupt status
D12	R	BINT13	0	BBus DMA channel #13 interrupt status
D11	R	BINT12	0	BBus DMA channel #12 interrupt status
D10	R	BINT11	0	BBus DMA channel #11 interrupt status
D09	R	BINT10	0	BBus DMA channel #10 interrupt status
D08	R	BINT9	0	BBus DMA channel #9 interrupt status
D07	R	BINT8	0	BBus DMA channel #8 interrupt status
D06	R	BINT7	0	BBus DMA channel #7 interrupt status
D05	R	BINT6	0	BBus DMA channel #6 interrupt status
D04	R	BINT5	0	BBus DMA channel #5 interrupt status
D03	R	BINT4	0	BBus DMA channel #4 interrupt status

Table 346: BBus DMA Interrupt Status register

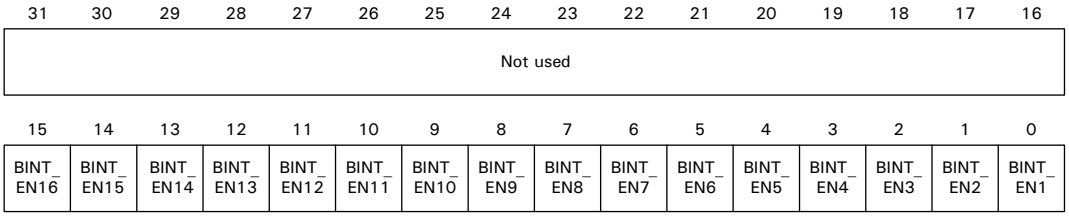
Bits	Access	Mnemonic	Reset	Description
D02	R	BINT3	0	BBus DMA channel #3 interrupt status
D01	R	BINT2	0	BBus DMA channel #2 interrupt status
D00	R	BINT1	0	BBus DMA channel #1 interrupt status

Table 346: BBus DMA Interrupt Status register

BBus DMA Interrupt Enable register

Address: 9060 0064

The BBus DMA Interrupt Enable register allows you to enable or disable the BBus DMA interrupts on an individual basis. Writing a 1 enables the interrupt.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:16	R	Not used	0x0	Always read as 0x0
D15	R/W	BINT_EN16	0	BBus DMA channel #16 interrupt enable
D14	R/W	BINT_EN15	0	BBus DMA channel #15 interrupt enable
D13	R/W	BINT_EN14	0	BBus DMA channel #14 interrupt enable
D12	R/W	BINT_EN13	0	BBus DMA channel #13 interrupt enable
D11	R/W	BINT_EN12	0	BBus DMA channel #12 interrupt enable
D10	R/W	BINT_EN11	0	BBus DMA channel #11 interrupt enable
D09	R/W	BINT_EN10	0	BBus DMA channel #10 interrupt enable
D08	R/W	BINT_EN9	0	BBus DMA channel #9 interrupt enable

Table 347: BBus DMA Interrupt Enable register

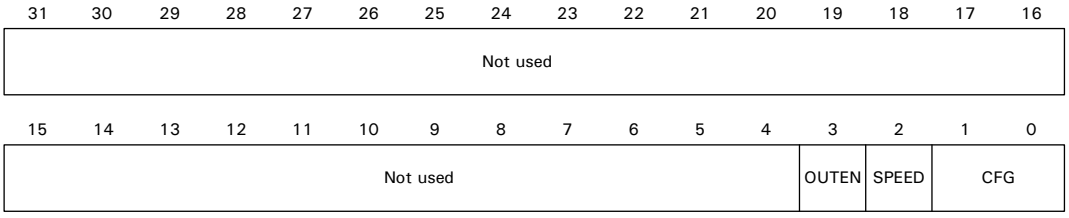
Bits	Access	Mnemonic	Reset	Description
D07	R/W	BINT_EN8	0	BBus DMA channel #8 interrupt enable
D06	R/W	BINT_EN7	0	BBus DMA channel #7 interrupt enable
D05	R/W	BINT_EN6	0	BBus DMA channel #6 interrupt enable
D04	R/W	BINT_EN5	0	BBus DMA channel #5 interrupt enable
D03	R/W	BINT_EN4	0	BBus DMA channel #4 interrupt enable
D02	R/W	BINT_EN3	0	BBus DMA channel #3 interrupt enable
D01	R/W	BINT_EN2	0	BBus DMA channel #2 interrupt enable
D00	R/W	BINT_EN1	0	BBus DMA channel #1 interrupt enable

Table 347: BBus DMA Interrupt Enable register

USB Configuration register

Address: 9060 0070

The USB Configuration register contains power-on USB configuration information. Write to this register only when the USB module is in reset, as indicated by the USB field in the Master Reset register (see page 535).



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:04	R	Not used	0x0	Always read as 0x0

Table 348: USB Configuration register

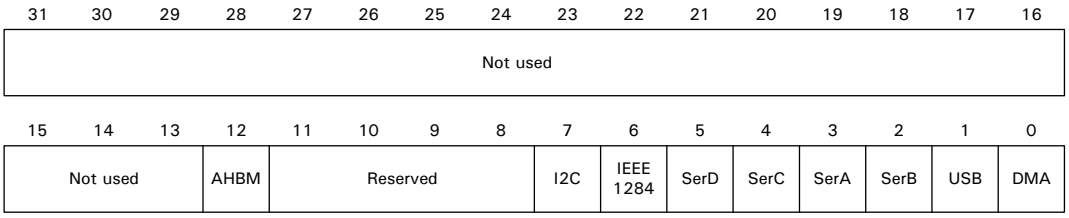
Bits	Access	Mnemonic	Reset	Description
D03	R/W	OUTEN	0	Enables the USB output driver during USB loopback testing. The output driver is enabled only when either the host or device indicates that it is driving the USB pins. Writing a 1 enables this feature.
D02	R/W	SPEED	1	0 Low speed (1.5 Mbps) 1 Full speed (12 Mbps) Defines the operational speed of the *USB device block*.
D01:00	R/W	CFG	11	**Configuration** 00 USB disabled 01 USB device mode; no software control 10 USB host mode; no software control 11 USB device mode; software control enabled Defines the operational mode of the USB module. This field can be modified only when the USB field in the Master Reset register is asserted (see page 535). For normal operation, this field should not need to be modified.

Table 348: USB Configuration register

Endian Configuration register

Address: 9060 0080

The Endian Configuration register contains the endian control for the BBus peripherals and the AHB bus master. NS9775 can be configured such that some peripherals transfer data in direct mode and some peripherals transfer data in DMA mode. Those that are accessed in direct mode must have their endian configuration match the AHB. The endian configuration of the AHB master must always match the AHB.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:13	R	Not used	0x0	Always read as 0x0
D12	R/W	AHBM	Reset to the value provided on strapping pin gpio[44]	**AHB bus master** 0 Little endian 1 Big endian
D11:08	N/A	Reserved	N/A	N/A
D07	R/W	I2C	0	**I^2C controller** 0 Little endian 1 Big endian
D06	R/W	IEEE1284	0	**IEEE 1284 controller** 0 Little endian 1 Big endian
D05	R/W	SerD	0	**Serial controller port D** 0 Little endian 1 Big endian
D04	R/W	SerC	0	**Serial controller port C** 0 Little endian 1 Big endian
D03	R/W	SerA	0	**Serial controller port A** 0 Little endian 1 Big endian

Table 349: Endian Configuration register

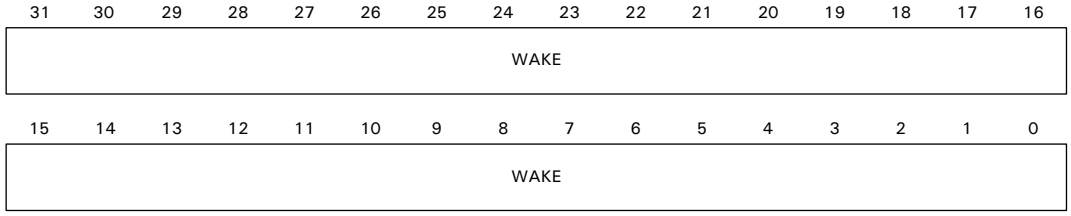
Bits	Access	Mnemonic	Reset	Description
D02	R/W	SerB	0	**Serial controller port B** 0 Little endian 1 Big endian
D01	R/W	USB	0	**USB** 0 Little endian 1 Big endian This does not affect the USB DMA controller.
D00	R/W	DMA	Reset to the value provided on strapping pin gpio[44]	**BBus DMA** 0 Little endian 1 Big endian This field controls both the general BBus DMA controller and the USB DMA controller.

Table 349: Endian Configuration register

ARM Wake-up register

Address: 9060 0090

The ARM Wake-up register contains the ARM wake-up word used only by Serial Controller Interface #1. This pattern, when found as the next entry in the receive FIFO, causes a wake-up signal to be asserted to the ARM.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:00	R/W	WAKE	0x0000_0000	Defines the byte-wise match in order for the Serial Controller to signal a wake-up to the ARM.

Table 350: ARM Wake-up register

I^2C Master/Slave Interface

CHAPTER 11

The I^2C master/slave interface provides an interface between the ARM CPU and the I^2C bus.

The I^2C master/slave interface basically is a parallel-to-serial and serial-to-parallel converter. The parallel data received from the ARM CPU has to be converted to an appropriate serial form to be transmitted to an external component using the I^2C bus. Similarly, the serial data received from the I^2C bus has to be converted to an appropriate parallel form for the ARM CPU. The I^2C master interface also manages the interface timing, data structure, and error handling.

Overview

The I^2C module is designed to be a master and slave. The slave is active *only* when the module is being addressed during an I^2C bus transfer; the master can arbitrate for and access the I^2C bus *only* when the bus is free (idle) — therefore, the master and slave are mutually exclusive.

Physical I^2C bus

The physical I^2C bus consists of two open-drain signal lines: serial data (SDA) and serial clock (SCL). Pullup resistors are required; see the standard I^2C bus specification for the correct value for the application. Each device connected to the bus is software-addressable by a unique 7- or 10-bit address, and a simple master/slave relationship exists at all times.

A master can operate as a master-transmitter (writes)) or a master-receiver (reads). The slaves respond to the received commands accordingly:

- In transmit mode (slave is read), the host interface receives character-based parallel data from the ARM. The module converts the parallel data to serial format and transmits the serial data to the I^2C bus.
- In receive mode (slave is written to), the I^2C bus interface receives 8-bit-based serial data from the I^2C bus. The module converts the serial data to parallel format and interrupts the host. The host's interrupt service routine reads the parallel data from the data register inside the I^2C module. The serial data stream synchronization and throttling are done by modulating the serial clock. Serial clock modulation can be controlled by both the transmitter and receiver, based in their hosts' service speed.

The I^2C is a true multi-master bus with collision detection and arbitration to prevent data corruption when two or more masters initiate transfer simultaneously. If a master loses arbitration during the addressing stage, it is possible that the winning master is trying to address the transfer. The losing master must therefore immediately switch over to its slave mode.

The on-chip filtering rejects spikes on the bus data line to preserve data integrity. The number of ICs that can be connected to the same bus is limited only by a maximum bus capacity of 400 pf.

I²C external addresses

I²C external [bus] addresses are allocated as two groups of eight addresses (0000XXX and 1111XXX), as shown in Table 351.

Slave address	R/W bit	Description
0000 000	0	General call address
0000 000	1	START byte (not supported in NS9775)
0000 001	X	CBUS address (not supported in NS9775)
0000 010	X	Reserved for different bus format
0000 011	X	Reserved
0000 1xx	X	hs-mode master code (not supported in NS9775)
1111 1xx	X	Reserved
1111 0xx	X	10-bit slave address

Table 351: Reserved slave addresses

The general call address is for addressing all devices connected to the I²C bus. A device can ignore this address by not issuing an acknowledgement. The meaning of the general call address is always specified in the second byte.

I²C command interface

The I²C module converts parallel (8-bit) data to serial data and serial data to parallel data between the NS9775 and the I²C bus, using a set of interface registers.

- The primary interface register for transmitting data is the CMD_TX_DATA_REG (write-only).
- The primary interface register for receiving data is the STATUS_RX_DATA_REG (read-only).

Locked interrupt driven mode

I^{2}C operates in a *locked interrupt driven mode*, which means that each command issued must wait for an interrupt response before the next command can be issued (illustrated in "Flow charts," beginning on page 568).

The first bit of the command — 0 or 1 — indicates to which module — master or slave, respectively — the command in the CMD field (of the CMD_TX_DATA_REG; see page 560) is sent. The master module can be sent a master command only; the slave module can be sent a slave command only (see "Master and slave module commands," beginning on page 558, for a list of commands). If a command is sent to the master module, that module is locked until a command acknowledgement is given. Similarly, if a command is sent to the slave module, the slave module is locked until it receives a command acknowledgement. With either module, the acknowledgement can be any interrupt associated with that module. When a module is locked, another command must not be sent to that module.

The command lock status can be checked in the STATUS_RX_DATA_REG.

Master module and slave module commands

The I^{2}C master recognizes four high-level commands, which are used in the CMD field of the Command register (see page 560); the I^{2}C slave recognizes two high-level commands:

Command	Name	Description
00_{hex}	M_NOP	No operation.
04_{hex}	M_READ	Start reading bytes from slave.
05_{hex}	M_WRITE	Start writing bytes to slave.
06_{hex}	M_STOP	Stop this transaction (give up the I^{2}C bus).
10_{hex}	S_NOP	No operation. This command is necessary for 16-bit mode, providing data in TX_DATA_REG without a command.
16_{hex}	S_STOP	Stop transaction by not acknowledging the byte received.

Table 352: Master and slave module commands

Bus arbitration

Any M_READ or M_WRITE command causes the I^2C module to participate in the bus arbitration process when the I^2C bus is free (idle). If the module becomes the new bus owner, the transaction goes through. If the module loses bus arbitration, an M_ARBIT_LOST interrupt is generated to the host processor and the command must be reissued.

I^2C registers

All registers have 8-bit definitions, but must be accessed in pairs. For example, TX_DATA_REG and CMD_REG are written simultaneously and RX_DATA_REG and STATUS_REG are read simultaneously.

Table 353 shows the register addresses.

Register	Description
9050 0000	Command Transmit Data register (CMD_TX_DATA_REG) Status Receive Data register (STATUS_RX_DATA_REG)
9050 0004	Master Address register
9050 0008	Slave Address register
9050 000C	Configuration register

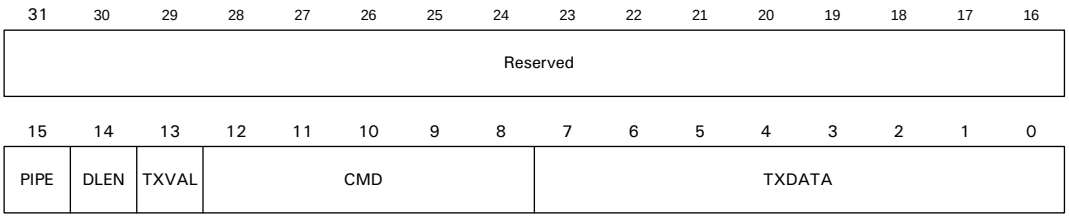
Table 353: I^2C register address map

After a reset, all registers are set to the initial value. If an unspecified register or bit is read, a zero is returned.

Command Transmit Data register

Address: 9050 0000

The Command Transmit Data (CMD_TX_DATA_REG) register is the primary interface register for transmission of data between the NS9775 BBus and I^2C bus. *This register is write only.*



Register bit assignment

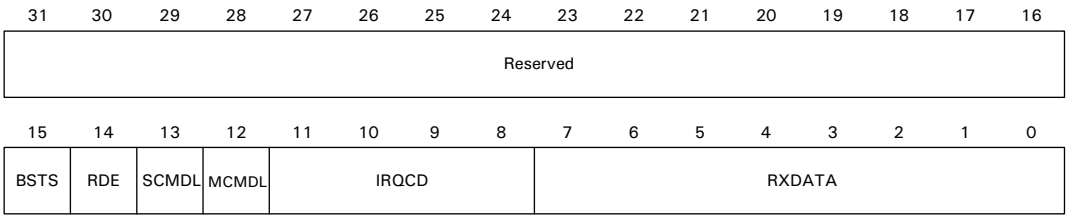
Bits	Access	Mnemonic	Reset	Description
D31:16	N/A	Reserved	N/A	**N/A**
D15	W	PIPE	00_{hex}	**Pipeline mode** Must be set to 0.
D14	W	DLEN	00_{hex}	**I^2C DLEN port** (iic_dlen) Must be set to 0.
D13	W	TXVAL	00_{hex}	**Provide new transmit data in** CMD_TX_DATA_REG (tx_data_val).
D12:08	W	CMD	00_{hex}	Command to be sent (see "Master and slave module commands," beginning on page 558)
D07:00	W	TXDATA	00_{hex}	Transmit data to I^2C bus.

Table 354: CMD_REG and TX_DATA_REG

Status Receive Data register

Address: 9050 0000

The Status Receive Data register (STATUS_RX_DATA_REG) is the primary interface register for receipt of data between the NS9775 BBus and I^2C bus. *This register is read only.*



Register bit assignment

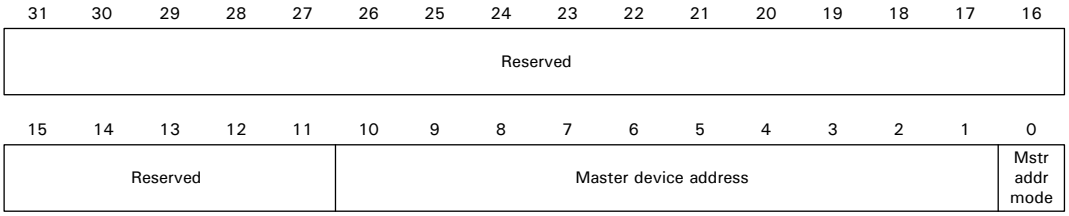
Bits	Access	Mnemonic	Reset	Description
D31:16	N/A	Reserved	N/A	**N/A**
D15	R	BSTS	N/A	**Bus status (master only)** 0 Bus is free 1 Bus is occupied
D14	R	RDE	N/A	**Receive data enable (**rx_data_en**)** Received data is available.
D13	R	SCMDL	N/A	**Slave command lock** The Slave Command register is locked.
D12	R	MCMDL	N/A	**Master command lock** The Master Command register is locked.
D11:08	R	IRQCD	N/A	**Interrupt codes** (irq_code) The interrupt is cleared if this register is read. See "Interrupt Codes" on page 565 for more information.
D07:00	R	RXDATA	N/A	**Received data from I^2C bus** Together with a RX_DATA interrupt, this register provides a received byte (see Table 359: "Master/slave interrupt codes" on page 566).

Table 355: STATUS_REG and RX_DATA_REG

Master Address register

Address: 9050 0004

If using 7-bit addressing, the master device address field uses only bits D07:01; otherwise, all 10 bits are used.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D10:01	R/W	MDA	00_{hex}	**Master device address** Used for selecting a slave. ■ Represents bits 6:0 of the device address if using 7-bit address. D10:08 are not used. ■ Represents bits 9:0 of device address if using 10-bit address.
D00	R/W	MAM	00_{hex}	**Master addressing mode** 0 7 bit address mode 1 10 bit address mode

Table 356: Master Address register (7-bit and 10-bit)

Slave Address register

Address: 9050 0008

If using 7-bit addressing, the slave device address field uses only bits D07:01; otherwise, bits 10:01 are used.

Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D11	R/W	GCA	00_{hex}	**General call address (**`s_gca_irq_en`**)** Enable the general call address. Default value is 1.
D10:01	R/W	SDA	00_{hex}	**Slave device address** Default value is $7F_{hex}$. ■ Represents bits 6:0 of device address if using 7-bit address; D10:08 are not used. ■ Represents bits 9:0 of device address if using 10-bit address.
D00	R/W	SAM	00_{hex}	**Slave addressing mode** 0 7 bit address mode 1 10 bit address mode

Table 357: Slave Address register (7-bit and 10-bit)

Configuration register

Address: 9050 000C

The Configuration register controls the timing on the I^2C bus. This register also controls the external interrupt indication, which can be disabled.

The I^2C bus clock timing is programmable by the `scl_ref` value (`D08:00`). The timing parameter for standard mode is as follows:

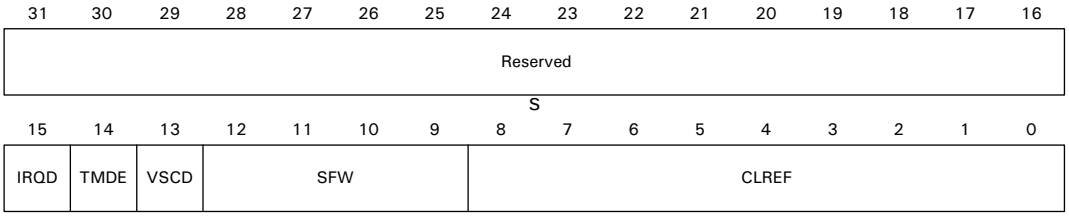
```
I2C_bus_clock = clk / ((CLREF*2) + 4 + scl_delay)
          clk = cpu_clk/4
```

Note: In noisy environments and fast-mode transmission, spike filtering can be applied to the received I^2C data and clock signal. The spike filter evaluates the incoming signal and suppresses spikes. The maximum length of the suppressed spikes can be specified in the spike filter width field of the Configuration register (see page 565).

The timing parameter for fast-mode is as follows:

```
I2C_bus_clock = (4 / 3) x (clk / ((CLREF*2) + 4 + scl_delay))
```

`scl_delay` is influenced by the SCL rise time.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:16	N/A	Reserved	N/A	N/A
D15	R/W	IRQD	0	**Mask the interrupt to the ARM CPU** (`irq_dis`) Must be set to 0.

Table 358: Configuration register

Bits	Access	Mnemonic	Reset	Description
D14	R/W	TMDE	1	**Timing characteristics of serial data and serial clock** 0 Standard mode 1 Fast mode
D13	R/W	VSCD	1	**Virtual system clock divider for master and slave** Must be set to 0.
D12:09	R/W	SFW	F_{hex}	**Spike filter width** A default value of 1 is recommended. Available values are 0–15.
D08:00	R/W	CLREF	00_{hex}	**clk_ref[9:1]** The I2C clock on port iic_scl_out is generated by the system clock divided by the 10-bit value of clk_ref. **Note:** The LSB of clk_ref cannot be programmed, and is set to 0 internally. The programmed value of clk_ref[9:1] must be greater than 3.

Table 358: Configuration register

Interrupt Codes

Interrupts are signaled in the `irq_code` field in the `STATUS_REG`, by providing the appropriate interrupt code (see Table 359: "Master/slave interrupt codes" on page 566). The ARM CPU waits for an interrupt by polling the `STATUS_REG` or checking the `irq` signal. An interrupt is cleared by reading the `STATUS_REG`, which also forces the `irq` signal down (minimum one cycle if another interrupt is stored).

Note: `RX_DATA_REG` contains only a received byte if it is accessed after a `RX_DATA` master or slave interrupt is signaled. At all other times, the internal master or slave shift register is accessed with `RX_DATA_REG` (see "Status Receive Data register" on page 561).

Code	Name	Master/slave	Description
0_{hex}	NO_IRQ	N/A	No interrupt active
1_{hex}	M_ARBIT_LOST	Master	Arbitration lost; the transfer has to be repeated
2_{hex}	M_NO_ACK	Master	No acknowledge by slave
3_{hex}	M_TX_DATA	Master	TX data required in register TX_DATA
4_{hex}	M_RX_DATA	Master	RX data available in register RX_DATA
5_{hex}	M_CMD_ACK	Master	Command acknowledge interrupt
6_{hex}	N/A	N/A	Reserved
7_{hex}	N/A	N/A	Reserved
8_{hex}	S_RX_ABORT	Slave	The transaction is aborted by the master before the slave performs a NO_ACK.
9_{hex}	S_CMD_REQ	Slave	Command request
A_{hex}	S_NO_ACK	Slave	No acknowledge by master (TX_DATA_REG is reset)
B_{hex}	S_TX_DATA_1ST	Slave	TX data required in register TX_DATA, first byte of transaction
C_{hex}	S_RX_DATA_1ST	Slave	RX data available in register RX_DATA, first byte of transaction
D_{hex}	S_TX_DATA	Slave	TX data required in register TX_DATA
E_{hex}	S_RX_DATA	Slave	RX data available in register RX_DATA
F_{hex}	S_GCA	Slave	General call address

Table 359: Master/slave interrupt codes

Software driver

The I^2C master software driver uses three commands only:

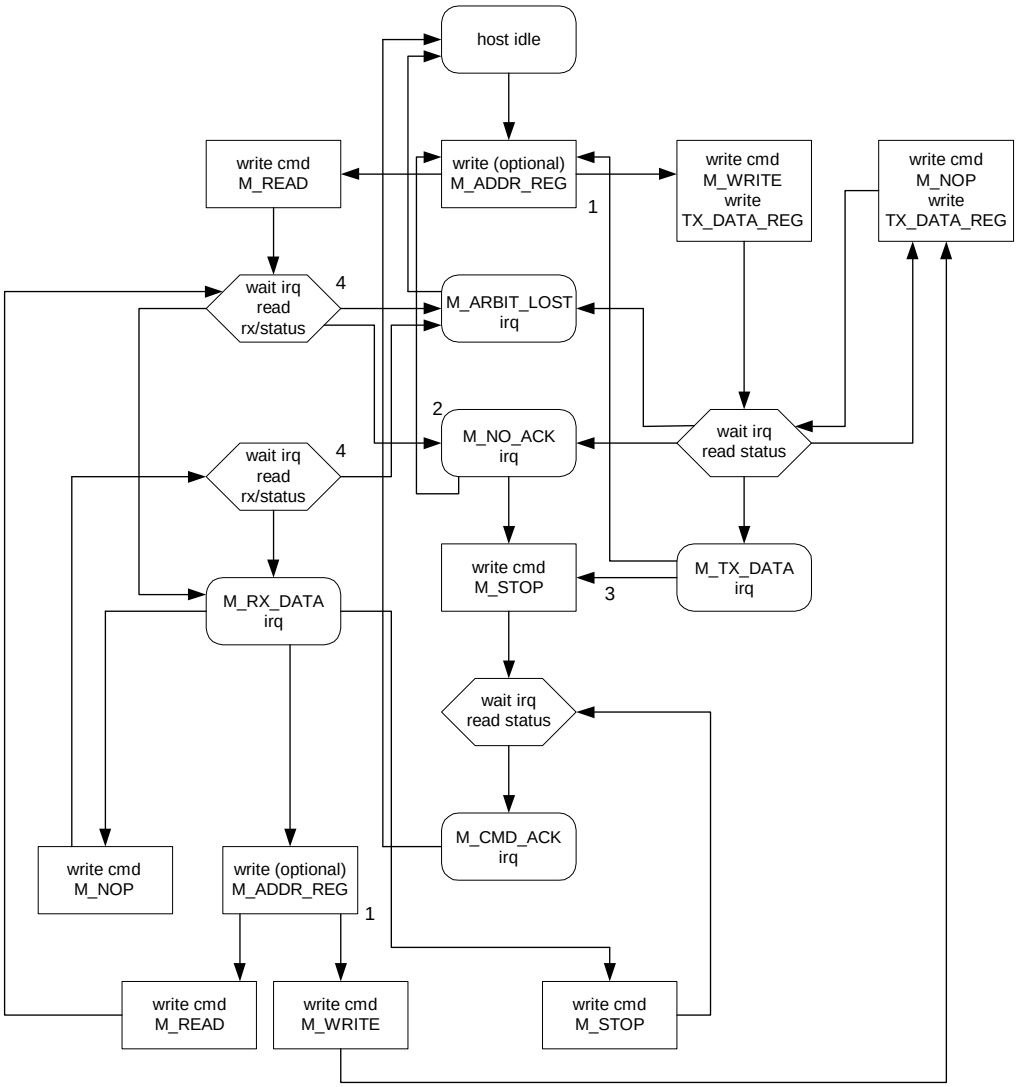
- M_READ to start a read sequence
- M_WRITE to start a write sequence
- M_STOP to give up the I^2C bus

If, during a read or write sequence, another M_READ or M_WRITE is requested by the ARM CPU, a restart is performed on the I^2C bus. This opens the opportunity to provide a new slave device address in the MAster Address register before the command request.

The I^2C slave high level driver identifies one command: S_STOP, to discontinue a transaction. After this command, the slave remains inactive until the next start condition on the I^2C bus. If a slave is accessed by a master, it generates S_RX_DATA and S_TX_DATA interrupts (see "Master/slave interrupt codes" on page 566). To distinguish the transactions from each other, special S_RX_DATA_1ST and S_TX_DATA_1ST interrupts are generated for the transmitted byte.

Flow charts

Master module (normal mode, 16-bit)



Notes:

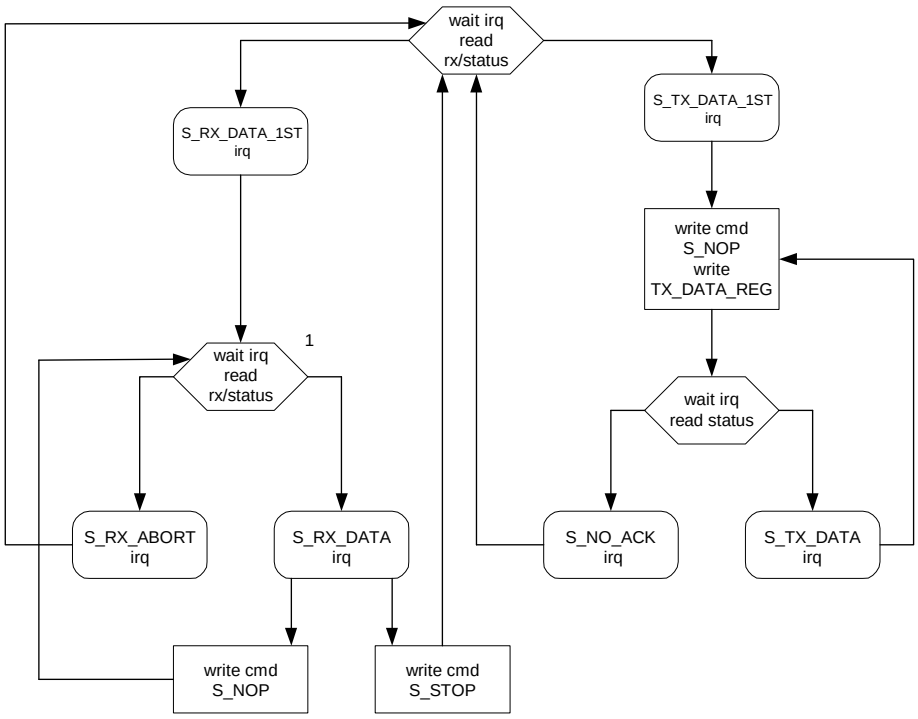
1 Writing M_ADDR_REQ is not required if the device address is not changed.

2 Read on a non-existing slave.

3 Do not wait for the slave to perform a NO_ACK.

4 STATUS_REG and RX_DATA_REG are read simultaneously.

Slave module (normal mode, 16-bit)



Note:

1 STATUS_REG and RX_DATA_REG are read simultaneously.

LCD Controller

CHAPTER 12

The NS9775 LCD (Liquid Crystal Display) controller is a DMA master module that connects to the AHB bus. The LCD controller provides the signals required to interface directly to TFT and STN color and monochrome LCD panels.

LCD controller timing diagrams can be found in the Timing chapter.

LCD features

The NS9775 LCD controller provides these features:

- Dual 64-deep, 32-bit wide FIFOs, for buffering incoming display data
- Support for color and monochrome single- and dual-panel for Super Twisted Nematic (STN) displays with 4- or 8-bit interfaces
- Support for Thin Film Transistor (TFT) color displays
- Resolution programmable up to 1024 x 768
- 15 gray-level mono, 3375 color STN, and 64K color TFT support
  - Patented gray-scale algorithm
- 1, 2, or 4 bits-per-pixel (bpp) palettized displays for mono STN
- 1, 2, 4, or 8 bpp palettized color displays for color STN and TFT
- 16 bpp true-color non-palettized, for color STN and TFT
- 24 bpp true-color non-palettized for TFT
- Programmable timing for different display panels
- 256 entry, 16-bit palette RAM, arranged as a 128 x 32-bit RAM
- Frame, line, and pixel clock signals
- AC bias signal for STN, data enable signal for TFT panels
- Support for little and big endian, as well as Windows CE data formats

Programmable parameters

These key parameters are programmable:

- Horizontal front and back porch
- Horizontal synchronization pulse width
- Number of pixels per line
- Vertical front and back porch
- Vertical synchronization pulse width
- Number of lines per panel
- Number of panel clocks per line

- Signal polarity, active high or low
- AC panel bias
- Panel clock frequency
- Bits-per-pixel
- Display type, STN mono/color or TFT
- STN 4- or 8-bit interface mode
- STN dual- or single-panel mode
- Little endian, big endian, or WinCE mode
- Interrupt generation event

LCD panel resolution

The LCD can be programmed to support a wide range of panel resolutions, including but not limited to:

- 320 x 200, 320 x 240
- 640 x 200, 640 x 240, 640 x 480
- 800 x 600
- 1024 x 768

LCD panel support

The LCD controller supports these types of panels:

- Active matrix TFT panels with up to 24-bit bus interface
- Single-panel monochrome STN panels (4-bit and 8-bit bus interface)
- Dual-panel monochrome STN panels (4-bit and 8-bit bus interface per panel)
- Single-panel color STN panels, 8-bit bus interface
- Dual-panel color STN panels, 8-bit bus interface per panel

Number of colors

The number of colors supported differs per panel type.

TFT panels

TFT panels support one or more of these color modes:

- 1 bpp, palettized, 2 colors selected from available colors
- 2 bpp, palettized, 4 colors selected from available colors
- 4 bpp, palettized, 16 colors selected from available colors
- 8 bpp, palettized, 256 colors selected from available colors
- 16 bpp, direct 5:5:5 RGB, with one bpp usually not used. This pixel is still output, and can be used as a *bright* bit to connect to the least significant bit (lsb) of R, G, and B components of a 6:6:6 TFT panel.
- 24 bpp, direct 8:8:8 RGB, providing over 16 million colors

Each 16-bit palette entry is made up of five bpp (RGB) plus a common intensity bit, which provides better memory use and performance compared with a full six bpp structure. The total amount of colors supported can be doubled from 32K to 64K if the intensity bit is used and applied to all three color components simultaneously.

Color STN panels

Color STN panels support one or more of these color modes:

- 1 bpp, palettized, 2 colors selected from 3375
- 2 bpp, palettized, 4 colors selected from 3375
- 4 bpp, palettized, 16 colors selected from 3375
- 8 bpp, palettized, 256 colors selected from 3375
- 16 bpp, direct 4:4:4 RGB, with 4 bpp not used

Mono STN panels

Mono STN panels support one or more of these modes:

- 1 bpp, palettized, 2 grayscales selected from 15
- 2 bpp, palettized, 4 grayscales selected from 15
- 4 bpp, palettized, 15 grayscales selected from 15

LCD power up and power down sequence support

This procedure provides an example of how the LCD controller can be programmed to provide the powerup sequence to an LCD panel (see Figure 88, "Power up and power down sequences," on page 576):

1. V_{DD} is applied simultaneously to the NS9775 and panel display driver logic. The following signals are pulled up to V_{DD} until the LCD controller is configured: CLLP, CLCP, CLFP, CLAC, CLD[23:0], and CLLE.
2. After the LCD controller is configured, a 1 is written to the LcdEn bit in the LCDControl register. This enables the CLLP, CLCP, CLFP, CLAC, and CLLE signals, but the CLD[23:0] signals will be low.
3. When the signals in Step 2 have stabilized, the contrast voltage, V_{EE} (which is not controlled or supplied by the LCD controller), is applied where appropriate. If required, a software timer routine can be used to provide the minimum display specific delay time between application of V_{DD} and application of V_{EE}.
4. If required, a software timer routine can be used to provide the minimum display specific delay time between application of the control signals and power to the panel display. When the software timer routine completes, power is applied to the panel by writing a 1 to the LcdPwr bit in the LcdControl register, which, in turn, sets the CLPOWER signal high and enables the CLD[23:0] signals into their active state. The CLPOWER signal gates the power to the LCD panel.

The power down sequence is the reverse of the powerup procedure, with the respective register bits written to 0 rather than 1.

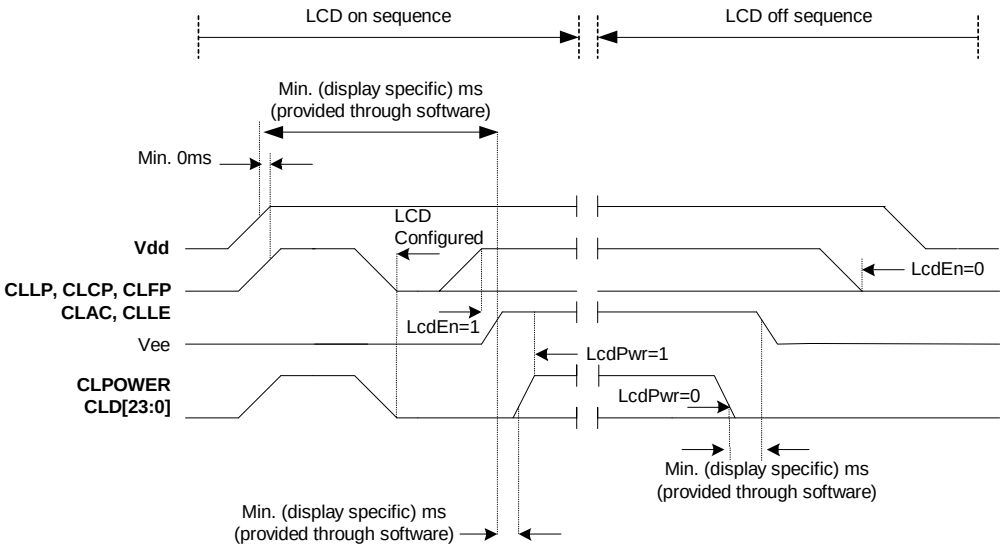


Figure 88: Power up and power down sequences

LCD controller functional overview

The LCD controller translates pixel-coded data into the required formats and timing to drive a variety of single and dual mono and color LCDs.

The controller supports passive STN and active TFT LCD display types.

- STN display panels require algorithmic pixel pattern generation to provide pseudo-grayscaling on mono displays or color creation on color displays.
- TFT display panels require the digital color value of each pixel to be applied to the display data units.

Packets of pixel-coded data are fed, through the AHB interface, to two independent, 64-deep, 32-bit wide DMA FIFOs, which act as input data flow buffers. The buffered pixel-coded data is then unpacked using a pixel serializer.

Depending on the LCD type and mode, the unpacked data can represent one of the following:

- An actual true display gray or color value
- An address to a 256 x 16 bit wide palette RAM gray or color value

With STN displays, either a value obtained from the addressed palette location or the true value is passed to the grayscaling generators. The hardware-coded grayscale algorithm logic sequences the addressed pixels activity over a programmed number of frames to provide the proper display appearance.

With TFT displays, either an addressed palette value or true color value is passed directly to the output display drivers, bypassing the grayscaling algorithm logic.

Clocks

The NS9775 LCD controller requires separate AHB (HCLK) and LCD (CLCDCLK) input clocks. The source of CLCDCLK is programmable using the LCD panel select field in the Clock Configuration register. Table 360 shows the clock selections.

LCD panel clock select	CLCDCLK
000	HCLK
001	HCLK/2
010	HCLK/4
011	HCLK/8
1xx	lcdclk/2 **Note:** lcdclk is an external clock input to NS9775. A *divided-by-2* version of this value is sent to the LCD controller.

Table 360: CLCDCLK selection

The LCD controller uses CLCDCLK internally. The clock sent to the LCD panel (CLCP) normally is derived from CLCDCLK using the PCD (panel clock divisor) value in the LCDTiming2 register (see page 598). The LCD controller also can bypass the internal clock divider controlled by PCD and use CLCDCLK as CLCP directly by setting the BCD (bypass pixel clock divider) bit to 1 in the LCDTiming2 register (see page 596).

Signals and interrupts

The LCD controller provides a set of programmable display control signals, and generates individual interrupts for different conditions.

Programmable control signals

- LCD power panel enable
- Pixel clock
- Horizontal and vertical synchronization pulses
- Display bias

Individual interrupts

- Base address update signification
- Vertical compare
- Bus error

There is also a single combined interrupt that is generated when any of the individual interrupts become active.

Figure 89 shows the LCD controller module.

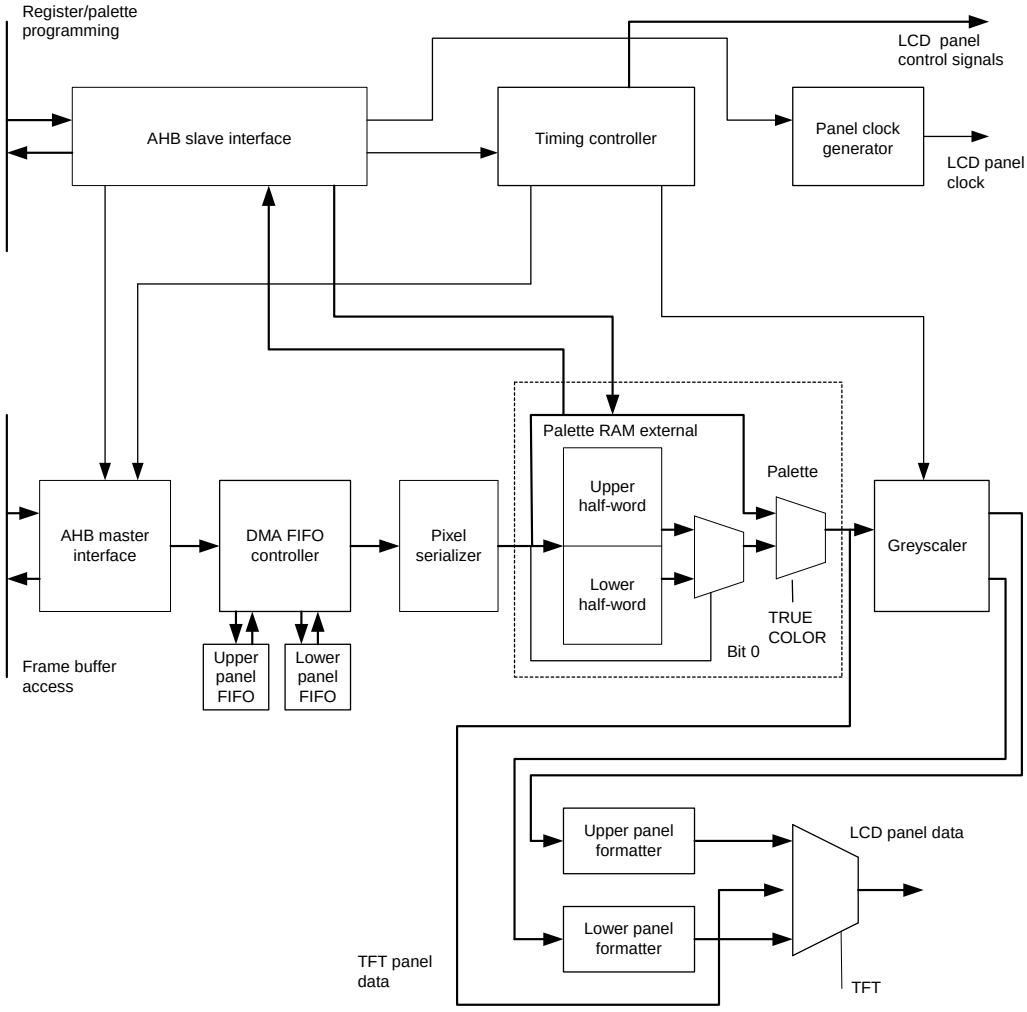


Figure 89: LCD controller block diagram

AHB interface

The AHB interface includes the AHB slave interface and the AHB master interface.

AHB master and slave interfaces

The AHB master interface transfers display data from memory to the LCD controller DMA FIFOs.

The AHB slave interface connects the LCD to the AHB bus and provides CPU accesses to the registers and palette RAM. The LCD controller AHB slave interface supports these features:

Dual DMA FIFOs and associated control logic

The pixel data accessed from memory is buffered by two DMA FIFOs, which can be controlled independently to cover single and dual panel LCD types. Each FIFO is 64 words deep by 32 bits wide, and can be cascaded to form a 128-word deep FIFO in single panel mode. The FIFO input ports are connected to the AHB interface and the output port feeds the pixel serializer.

Synchronization logic is used to transfer the pixel data from the AHB HCLK domain to the CLCDCLK clock domain. The DMA FIFOs are clocked by HCLK.

The water level marks within each FIFO are set such that each FIFO requests data when at least four locations become available.

Pixel serializer

The pixel serializer block reads the 32-bit wide LCD data from DMA FIFO output port, and extracts 24, 16, 8, 4, 2, or 1 bpp, depending on the current mode of operation. The LCD controller supports big endian, little endian, and WinCE data formats. In dual panel mode, data is read alternately from the upper and lower DMA FIFOs. The mode of operation determines whether the extracted data is used to point to a color/grayscale value in the palette ram or is actually a true color value that can be applied directly to an LCD panel input.

The next six figures show the data structure in each DMA FIFO word corresponding to the Endianness and bpp combinations. For each of the three supported data formats, the required data for each panel display pixel must be extracted from the data word.

Figure 90 and Figure 91 show the data structure for little endian byte, little endian pixel — LBLP.

Figure 92 and Figure 93 show the data structure for big endian byte, big endian pixel — BBBP.

Figure 94 and Figure 95 show the data structure for little endian byte, big endian pixel — LBBP. (This is WinCE format.)

bpp	DMA FIFO OUTPUT BITS															
	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
1	p31	p30	p29	p28	p27	p26	p25	p24	p23	p22	p21	p20	p19	p18	p17	p16
2	p15		p14		p13		p12		p11		p10		p9		p8	
	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
4	p7				p6				p5				p4			
	3	2	1	0	3	2	1	0	3	2	1	0	3	2	1	0
8	p3								p2							
	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
16	p1															
	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
24	p0															
									23	22	21	20	19	18	17	16

Figure 90: LBLP, DMA FIFO output bits 31:16

bpp	DMA FIFO OUTPUT BITS															
	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	p15	p14	p13	p12	p11	p10	p9	p8	p7	p6	p5	p4	p3	p2	p1	p0
2	p7		p6		p5		p4		p3		p2		p1		p0	
	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
4	p3				p2				p1				p0			
	3	2	1	0	3	2	1	0	3	2	1	0	3	2	1	0
8	p1								p0							
	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
16	p0															
	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
24	p0															
	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

Figure 91: LBLP, DMA FIFO output bits 15:0

bpp	DMA FIFO OUTPUT BITS															
	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
1	p0	p1	p2	p3	p4	p5	p6	p7	p8	p9	p10	p11	p12	p13	p14	p15
2	p0		p1		p2		p3		p4		p5		p6		p7	
	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
4	p0				p1				p2				p3			
	3	2	1	0	3	2	1	0	3	2	1	0	3	2	1	0
8	p0								p1							
	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
16	p0															
	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
24	p0															
									23	22	21	20	19	18	17	16

Figure 92: BBBP, DMA FIFO output bits 31:16

bpp	DMA FIFO OUTPUT BITS															
	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	p16	p17	p18	p19	p29	p21	p22	p23	p24	p25	p26	p27	p28	p29	p30	p31
2	p8		p9		p10		p11		p12		p13		p14		p15	
	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
4	p4				p5				p6				p7			
	3	2	1	0	3	2	1	0	3	2	1	0	3	2	1	0
8	p2								p3							
	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
16	p1															
	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
24	p0															
	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

Figure 93: BBBP, DMA FIFO output bits 15:0

bpp	DMA FIFO OUTPUT BITS															
	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
1	p24	p25	p26	p27	p28	p29	p30	p31	p16	p17	p18	p19	p20	p21	p22	p23
2	p12		p13		p14		p15		p8		p9		p10		p11	
	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
4	p6				p7				p4				p5			
	3	2	1	0	3	2	1	0	3	2	1	0	3	2	1	0
8	p3								p2							
	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
16	p1															
	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
24	p0															
									23	22	21	20	19	18	17	16

Figure 94: LBBP, DMA FIFO output bits 31:16

bpp	DMA FIFO OUTPUT BITS															
	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	p8	p9	p10	p11	p12	p13	p14	p15	p0	p1	p2	p3	p4	p5	p6	p7
2	p4		p5		p6		p7		p0		p1		p2		p3	
	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
4	p2				p3				p0				p1			
	3	2	1	0	3	2	1	0	3	2	1	0	3	2	1	0
8	p1								p0							
	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
16	p0															
	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
24	p0															
	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

Figure 95: LBBP, DMA FIFO output bits 15:0

RAM palette

The palette RAM is a 256 x 16 bit dual port RAM, physically structured as 128 x 32 bit. This allows two entries to be written into the palette from a single word write access. The least significant bit of the serialized pixel data selects between upper and lower halves of the palette RAM. The half selected depends on the byte-ordering mode. In little endian mode, setting the least significant bit selects the upper half of the palette; in big endian mode, setting the least significant bit selects the lower half. Because WinCE byte ordering is little endian, setting the least significant byte results in selection of the upper half of the palette.

Pixel data values can be written and verified using the slave interface.

The palette RAM has independent controls and addresses for each port.

- Port1 is used as a read/write port, and is connected to the AHB slave interface. The palette entries can be written and verified through this port.
- Port2 is used as a read-only port, and is connected to the unpacker and grayscaler.

Table 361 shows the bit representation of each word in the palette.

Bit	Name	Description
31	I	Intensity/unused
30:26	B[4:0]	Blue palette data
25:20	G[4:0]	Green palette data
19:16	R[4:0]	Red palette data
15	I	Intensity/unused
14:10	B[4:0]	Blue palette data
09:05	G[4:0]	Green palette data
04:00	R[4:0]	Red palette data

Table 361: Palette data storage

For mono STN, only the red palette field bits (4:1) are used. In STN color mode, however, the green and blue [4:1] are also used.

Red and blue pixel data can be swapped to support BGR data format using the appropriate control register bit.

In 16- and 24-bpp TFT mode, the palette is bypassed and the pixel serializer output is used as the TFT panel data.

Grayscaler

A unique grayscale algorithm drives mono and color STN panels.

- For mono displays, the algorithm provides 15 grayscales.
- For STN color displays, the three color components (red, green, and blue) are grayscaled simultaneously, resulting in 3375 (15 x 15 x 15) colors available. The grayscaler transforms each 4-bit gray value into a sequence of activity-per-pixel over several frames, relying somewhat on the display characteristics, to give representation of grayscales and color.

Upper and lower panel formatters

Each formatter consists of three 3-bit (red, green, and blue) *shift left* registers. Red, green, and blue pixel data bit values from the grayscaler are shifted concurrently into the respective registers. When enough data is available, a byte is constructed by multiplexing the registered data to the correct bit position to satisfy the RGB data pattern of the LCD panel. The byte is transferred to the 3-byte FIFO, which has enough space to store eight color pixels.

Panel clock generator

The panel clock generator block output is the panel clock. This is a divided down version of `CLCDCLK`, and can be programmed in the range `CLCDCLK/2` to `CLCDCLK/33` to match the bpp data rate of the LCD panel.

Timing controller

The timing controller block's primary function is to generate the horizontal and vertical timing panel signals. The timing controller also provides the panel bias/ enable signal. Use the AHB slave interface to program these signals in the appropriate registers.

Generating interrupts

The LCD controller has three individually masked interrupts and a single combined interrupt. The single combined interrupt is asserted if any of the combined interrupts are asserted and unmasked.

External pad interface signals

The external pad interface signals are brought out through GPIO.

Signal name	Type	Description
CLPOWER	Output	LCD panel power enable
CLLP	Output	Line synchronization pulse (STN)/horizontal synchronization pulse (TFT)
CLCP	Output	LCD panel clock
CLFP	Output	Frame pulse (STN)/vertical synchronization pulse (TFT)
CLAC	Output	STN AC bias drive or TFT data enable output
CLD[23:0]	Output	LCD panel data
CLLE	Output	Line end signal

Table 362: External pad interface signals

LCD panel signal multiplexing details

The `CLLP`, `CLAC`, `CLFP`, and `CLLE` signals are common, but the `CLD[23:0]` bus has eight modes of operation:

- TFT 24-bit interface
- TFT 18-bit interface
- Color STN single panel
- Color STN dual panel
- 4-bit mono STN single panel
- 4-bit mono STN dual panel
- 8-bit mono STN single panel
- 8-bit mono STN dual panel

Table 363 shows which CLD[23:0] pins provide the pixel data to the STN panel for each mode of operation. The abbreviations used in the table are defined as follows:

- CUSTN = Color upper panel STN, dual and/or single panel
- CLSTN = Color lower panel STN, dual
- MUSTN = Mono upper panel STN, dual and/or single panel
- MLSTN = Mono lower panel STN, dual

Ext pin	GPIO pin & description	Color STN single panel	Color STN dual panel	4-bit mono STN single panel	4-bit mono STN dual panel	8-bit mono STN single panel	8-bit mono STN dual panel
CLD[23]	AA4 = LCD data bit 23 (O2)	N/A	N/A	N/A	N/A	N/A	N/A
CLD[22]	AB3 = LCD data bit 22 (O2)	N/A	N/A	N/A	N/A	N/A	N/A
CLD[21]	AE1 = LCD data bit 21 (O2)	N/A	N/A	N/A	N/A	N/A	N/A
CLD[20]	AD2 = LCD data bit 20 (O2)	N/A	N/A	N/A	N/A	N/A	N/A
CLD[19]	AF3 = LCD data bit 19 (O2)	N/A	N/A	N/A	N/A	N/A	N/A
CLD[18]	AE4 = LCD data bit 18 (O2)	N/A	N/A	N/A	N/A	N/A	N/A
CLD[17]	AD5 = LCD data bit 17 (O2)	N/A	N/A	N/A	N/A	N/A	N/A
CLD[16]	AC6 = LCD data bit16 (O2)	N/A	N/A	N/A	N/A	N/A	N/A
CLD[15]	AF4 = LCD data bit 15 (O2)	N/A	CLSTN[0][1]	N/A	N/A	N/A	MLSTN[0][1]
CLD[14]	AE5 = LCD data bit 14 (O2)	N/A	CLSTN[1]	N/A	N/A	N/A	MLSTN[1]
CLD[13]	AD6 = LCD data bit 13 (O2)	N/A	CLSTN[2]	N/A	N/A	N/A	MLSTN[2]
CLD[12]	AF5 = LCD data bit 12 (O2)	N/A	CLSTN[3]	N/A	N/A	N/A	MLSTN[3]
CLD[11]	AE6 = LCD data bit 11 (O2) AE8 = LCD data bit 11 (O2)	N/A	CLSTN[4]	N/A	MLSTN[0][1]	N/A	MLSTN[4]
CLD[10]	AD7 = LCD data bit 10 (O2) AD9 = LCD data bit 10 (O2)	N/A	CLSTN[5]	N/A	MLSTN[1]	N/A	MLSTN[5]
CLD[9]	AD8 = LCD data bit 9 (O2) AF8 = LCD data bit 9 (O2)	N/A	CLSTN[6]	N/A	MLSTN[2]	N/A	MLSTN[6]
CLD[8]	AF7 = LCD data bit 8 (O2) AE9 = LCD data bit 8 (O2)	N/A	CLSTN[7]	N/A	MLSTN[3]	N/A	MLSTN[7]

Table 363: LCD STN panel signal multiplexing

Ext pin	GPIO pin & description	Color STN single panel	Color STN dual panel	4-bit mono STN single panel	4-bit mono STN dual panel	8-bit mono STN single panel	8-bit mono STN dual panel
CLD[7]	AE8 = LCD data bit 7 (O1)	CUSTN[0][1]	CUSTN[0][1]	N/A	N/A	MUSTN[0]	MUSTN[0][1]
CLD[6]	AD9 = LCD data bit 6 (O1)	CUSTN[1]	CUSTN[1]	N/A	N/A	MUSTN[1]	MUSTN[1]
CLD[5]	AF8 = LCD data bit 5 (O1)	CUSTN[2]	CUSTN[2]	N/A	N/A	MUSTN[2]	MUSTN[2]
CLD[4]	AE9 = LCD data bit 4 (O1)	CUSTN[3]	CUSTN[3]	N/A	N/A	MUSTN[3]	MUSTN[3]
CLD[3]	AF9 = LCD data bit 3 (O1)	CUSTN[4]	CUSTN[4]	MUSTN[0]	MUSTN[0][1]	MUSTN[4]	MUSTN[4]
CLD[2]	AD10 = LCD data bit 2 (O1)	CUSTN[5]	CUSTN[5]	MUSTN[1]	MUSTN[1]	MUSTN[5]	MUSTN[5]
CLD[1]	AE10 = LCD data bit 1 (O1)	CUSTN[6]	CUSTN[6]	MUSTN[2]	MUSTN[2]	MUSTN[6]	MUSTN[6]
CLD[0]	AF10 = LCD data bit 0 (O1)	CUSTN[7]	CUSTN[7]	MUSTN[3]	MUSTN[3]	MUSTN[7]	MUSTN[7]

1 This data bit corresponds to the first "pixel position." For example, for an 8-bit mono STN display, `CUSTN[0]` is the leftmost pixel on the panel and `CUSTN[7]` is the rightmost pixel within the 8-bit data. For a color STN display, bits [7, 6, 5] form the leftmost pixel.

Table 363: LCD STN panel signal multiplexing

Table 364 shows which `CLD[23:0]` pins are used to provide the pixel data to the TFT panel for each mode of operation.

External pin	TFT 24 bit	TFT 18 bit
CLD[23]	Blue[7]	Reserved
CLD[22]	Blue[6]	Reserved
CLD[21]	Blue[5]	Reserved
CLD[20]	Blue[4]	Reserved
CLD[19]	Blue[3]	Reserved
CLD[18]	Blue[2]	Reserved
CLD[17]	Blue[1]	Blue[4]
CLD[16]	Blue[0]	Blue[3]

Table 364: LCD TFT panel signal multiplexing

External pin	TFT 24 bit	TFT 18 bit
CLD[15]	Green[7]	Blue[2]
CLD[14]	Green[6]	Blue[1]
CLD[13]	Green[5]	Blue[0]
CLD[12]	Green[4]	Intensity bit
CLD[11]	Green[3]	Green[4]
CLD[10]	Green[2]	Green[3]
CLD[9]	Green[1]	Green[2]
CLD[8]	Green[0]	Green[1]
CLD[7]	Red[7]	Green[0]
CLD[6]	Red[6]	Intensity bit
CLD[5]	Red[5]	Red[4]
CLD[4]	Red[4]	Red[3]
CLD[3]	Red[3]	Red[2]
CLD[2]	Red[2]	Red[1]
CLD[1]	Red[1]	Red[0]
CLD[0]	Red[0]	Intensity bit

Table 364: LCD TFT panel signal multiplexing

Note: The intensity bit, if used, should be connected to the LSB (that is, `RED[0]`, `GREEN[0]`, `BLUE[0]`) input of the LCD TFT panel.

Registers

Table 365 lists the LCD controller registers. All configuration registers must be accessed as 32-bit words and as single accesses only. No bursting is allowed.

Address	Register	Description
A080 0000	LCDTiming0	Horizontal axis panel control
A080 0004	LCDTiming1	Vertical axis panel control
A080 0008	LCDTiming2	Clock and signal polarity control
A080 000C	LCDTiming3	Line end control
A080 0010	LCDUPBASE	Upper panel frame base address
A080 0014	LCDLPBASE	Lower panel frame base address
A080 0018	LCDINTRENABLE	Interrupt enable mask
A080 001C	LCDControl	LCD panel pixel parameters
A080 0020	LCDStatus	Raw interrupt status
A080 0024	LCDInterrupt	Final masked interrupts
A080 0028	LCDUPCURR	LCD upper panel current address value
A080 002C	LCDLPCURR	LCD lower panel current address value
A080 0030 – A080 01FC	Reserved	Reserved
A080 0200 – A080 03FC	LCDPalette	256 x 16-bit color palette

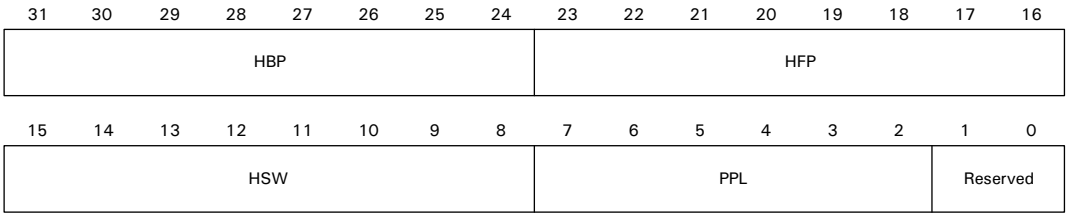
Table 365: LCD registers

LCDTiming0

Address: A080 0000

The LCDTiming0 register controls the horizontal axis panel, which includes:

- Horizontal synchronization pulse width (HSW)
- Horizontal front porch (HFP) period
- Horizontal back porch (HBP) period
- Pixels-per-line (PPL)



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:24	R/W	HBP	0x00	**Horizontal back porch** Number of CLCP periods between the negation of CLLP and the start of active data. Program this field with value minus 1. HBP specifies the number of pixel clock periods inserted at the beginning of each line or row of pixels. HBP can generate a delay of 1 to 256 pixel clock cycles.
D23:16	R/W	HFP	0x00	**Horizontal front porch** Number of CLCP periods between the end of active data and the assertion of CLLP. Program this field with value minus 1. HFP sets the number of pixel clock periods at the end of each line or row of pixels, before CLLP is asserted. HFP can generate a period of 1 to 256 pixel clock cycles.
D15:08	R/W	HSW	0x00	**Horizontal synchronization pulse width** Width of the CLLP signal in CLCP periods. Program this field with value minus 1. HSW specifies the pulse width of the line clock in passive mode, or the horizontal synchronization pulse in active mode.

Table 366: LCDTiming0 register

Bits	Access	Mnemonic	Reset	Description
D07:02	R/W	PPL	0x00	**Pixels-per-line** Actual pixels-per-line = 16 * (PPL + 1) The PPL field specifies the number of pixels in each line or row of the screen. PPL is a 6-bit value that represents between 16 and 1024 PPL. PPL counts the number of pixel clocks that occur before HFP is applied (program the value required divided by 16, minus 1).
D01:00	N/A	Reserved	N/A	N/A

Table 366: LCDTiming0 register

Horizontal timing restrictions

DMA requests new data at the beginning of a horizontal display line. Some time must be allowed for the DMA transfer and for the data to propagate down the FIFO path in the LCD interface. The data path latency forces some restrictions on the usable minimum values for horizontal porch width in STN mode. The minimum values are HSW = 2 and HBP = 2. Table 367 shows the recommended minimum values for STN displays:

Mode	HSW	HBP	HFP	Panel clock divisor (PCD)
Single panel STN mode	3	5	5	1 (CLCDCLK/3)
Dual panel STN mode	3	5	5	5 (CLCDCLK/7)

Table 367: Minimum recommended values for STN displays

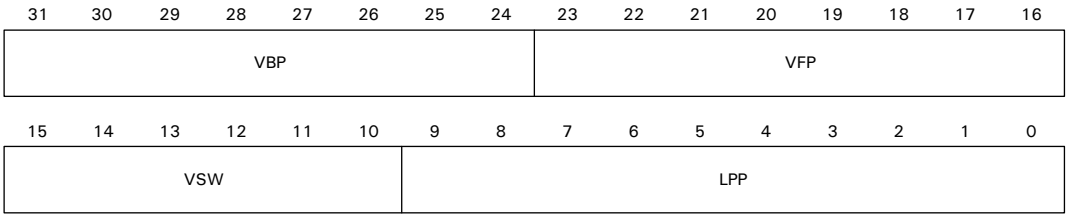
If sufficient time is given at the beginning of the line (for example, HSW is set to 6 and HBP is set to 10), data will not become corrupted for PCD = 4 (minimum value for dual panel mode).

LCDTiming1

Address: A080 0004

The LCDTiming1 register controls the vertical axis panel, which includes:

- Number of lines-per-panel (LPP)
- Vertical synchronization pulse width (VSW)
- Vertical front porch (VFP) period
- Vertical back porch (VBP period)



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:24	R/W	VBP	0x00	**Vertical back porch** Number of inactive lines at the start of a frame, after vertical synchronization period. Program this field to zero on passive displays, to avoid reduced contrast. VBP specifies the number of line clocks inserted at the beginning of each frame. The VBP count starts just after the CLFP for the previous frame has been negated for active mode, or the extra horizontal synchronization lines have been asserted as specified by the VSW field in passive mode. After this occurs, the count value in VBP sets the number of horizontal synchronization lines inserted before the next frame. VBP generates from 0 –255 extra line clock cycles.

Table 368: LCDTiming1 register

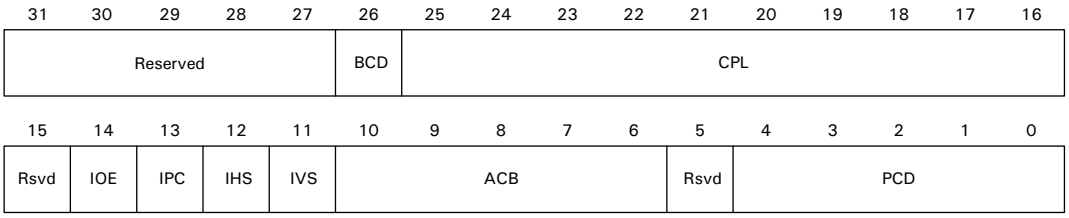
Bits	Access	Mnemonic	Reset	Description
D23:16	R/W	VFP	0x00	**Vertical front porch** Number of inactive lines at the end of the frame, before vertical synchronization period. Program this field to zero on passive displays, to avoid reduced contrast. VFP specifies the number of blank lines to insert at the end of each frame. Once a complete frame of pixels is transmitted to the LCD display, the value in VFP counts the number of horizontal synchronization lines to wait. After the count has elapsed, the vertical synchronization (CLFP) signal is asserted in active mode, or extra line clocks are inserted as specified by the VSW field in passive mode. VFP generates from 0 – 255 CLLP cycles.
D15:10	R/W	VSW	0x00	**Vertical synchronization pulse width** Number of horizontal synchronization lines. This value must be small (for example, program to 0) for passive STN LCDs. Program this field to the number of lines required minus one. The higher the value, the worse the contrast on STN LCDs. VSW specifies the pulse width of the vertical synchronization pulse. This field is programmed to the number of horizontal synchronization lines minus one.
D09:00	R/W	LPP	0x000	**Lines per panel** Number of active lines per screen. Program this field to number of lines required minus 1. LPP specifies the total number of lines or rows on the LCD panel being controlled; between 1 and 1024 lines are allowed. This field is programmed with the number of lines per LCD panel minus 1. For dual panel displays, this field is programmed with the number of lines on each of the upper and lower panels.

Table 368: LCDTiming1 register

LCDTiming2 register

Address: A080 0008

The LCDTiming2 register provides controls for the timing signals.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:27	N/A	Reserved	N/A	N/A
D26	R/W	BCD	0x0	**Bypass pixel clock divider** Set this field to 1 to bypass the pixel clock divider logic. Used primarily for TFT displays.
D25:16	R/W	CPL	0x000	**Clocks per line** Specifies the number of actual CLCP clocks to the LCD panel on each line. This is the number of pixels-per-line divided by 1 (TFT), 4 or 8 (mono STN), or 2 2/3 (color STN), minus one. Be sure this value is programmed properly, in addition to PPL; otherwise, the LCD controller does not work correctly.
D15	N/A	Reserved	N/A	N/A

Table 369: LCDTiming2 register

Bits	Access	Mnemonic	Reset	Description
D14	R/W	IOE	0x0	**Invert output enable** 0 CLAC output pin is active high in TFT mode 1 CLAC output pin is active low in TFT mode Selects the active polarity of the output enable signal in TFT mode. In this mode, the CLAC pin is used as an enable that indicates to the LCD panel when valid display data is available. In TFT mode, data is driven onto the LCD data lines at the programmed edge of CLCP when CLAC is in its active state.
D13	R/W	IPC	0x0	**Invert panel clock** 0 Data changes on the rising edge of CLCP. 1 Data changes on the falling edge of CLCP Controls the phasing of the LCD data relative to the LCD clock (CLCP). The NS9775 changes the data on the opposite edge of the clock used to capture the data.
D12	R/W	IHS	0x0	**Invert horizontal synchronization** 0 CLLP pin is active high and inactive low 1 CLLP pin is active low and inactive high Inverts the polarity of the CLLP signal.
D11	R/W	IVS	0x0	**Invert vertical synchronization** 0 CLFP pin is active high and inactive low 1 CLFP pin is active low and inactive high Inverts the polarity of the CLFP signal.
D10:06	R/W	ACB	0x00	**AC bias pin frequency** Applies only to STN displays, which require the pixel voltage polarity to be reversed periodically to prevent damage due to DC charge accumulation. Program this field with the required value minus one, to apply the number of line clocks between each toggle of the AC bias pin (CLAC). This field has no effect when the LCD controller is using TFT mode, which uses the CLAC pin as a data enable signal.
D05	N/A	Reserved	N/A	N/A

Table 369: LCDTiming2 register

Bits	Access	Mnemonic	Reset	Description
D04:00	R/W	PCD	0x00	**Panel clock divisor** Derives the LCD panel clock frequency CLCP from the CLCDCLK frequency: CLCP = CLCDCLK/(PCD+2) ■ For mono STN displays with a 4- or 8-bit interface, the panel clock is a factor of four and eight down on the actual individual pixel clock rate. ■ For color STN displays, 2 2/3 pixels are output per CLCP cycle, resulting in a panel clock of 0.375 times. ■ For TFT displays, the pixel clock divider can be bypassed by setting the LCDTiming2 BCD bit (D26). See "Panel clock divider restrictions" on page 598 for more information.

Table 369: LCDTiming2 register

Panel clock divider restrictions

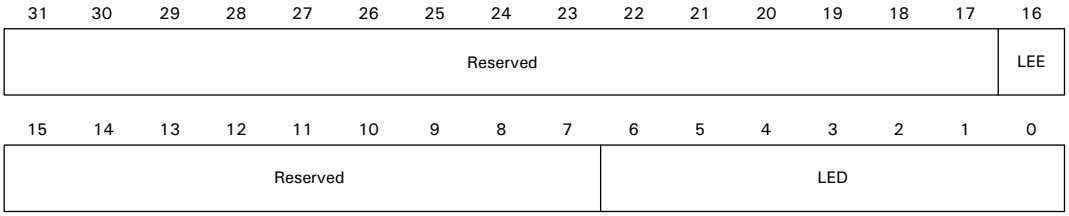
The data path latency forces some restrictions on the usable minimum values for the panel clock divider in STN modes:

- Single panel color mode: PCD = 1 (CLCP = CLCDCLK/3)
- Dual panel color mode: PCD = 4 (CLCP = CLCDCLK/6)
- Single panel mono 4-bit interface mode: PCD = 2 (CLCP = CLCDCLK/4)
- Dual panel mono 4-bit interface mode: PCD = 6 (CLCP = CLCDCLK/8)
- Single panel mono 8-bit interface mode: PCD = 6 (CLCP = CLCDCLK/8)
- Dual panel mono 8-bit interface mode: PCD = 14 (CLCP = CLCDCLK/16)

LCDTiming3

Address: A080 000C

LCDTiming3 controls whether the line-end signal, CLLE, is enabled. When enabled, a positive pulse, four CLCDCLK periods wide, is output on CLLE after a programmable delay from the last pixel of each display line. If the line-end signal is disabled, it is held permanently low.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:17	N/A	Reserved	N/A	N/A
D16	R/W	LEE	0x0	**LCD line-end enable** 0 CLLE disabled (held low) 1 CLLE signal active
D15:07	N/A	Reserved	N/A	N/A
D06:00	R/W	LED	0x00	**Line-end signal delay** Line-end signal delay from the rising edge of the last panel clock (CLCP). Program this field with number of CLCDCLK clock periods minus 1.

Table 370: LCDTiming3 register

LCDUPBASE and LCDLPBASE

Address: A080 0010 and A080 0014

LCDUPBASE and LCDLPBASE are the DMA base address registers, and program the base address of the frame buffer.

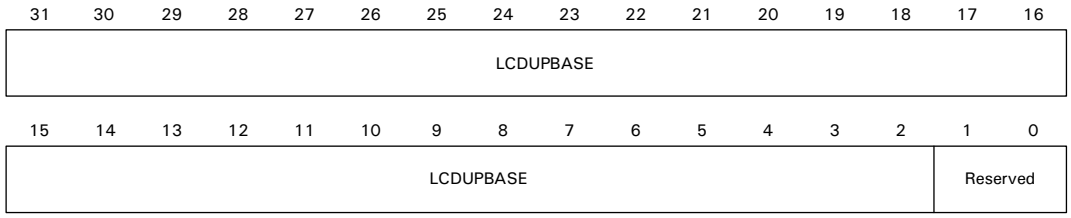
LCDUPBASE is used for these displays:

- TFT
- Single panel STN
- Upper panel of dual panel STN

LCDLPBASE is used for the lower panel of dual panel STN displays.

Important: You must initialize LCDUPBASE (and LCDLPBASE for dual panels) before enabling the LCD controller.

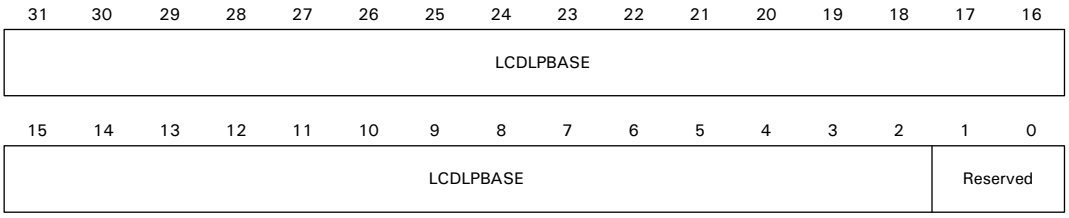
The base address value optionally can be changed mid-frame, to allow double-buffered video displays to be created. These registers are copied to the corresponding current registers at each LCD vertical synchronization, which then cause the LNBU bit (in the LCDStatus register; see page 606) to be set and an optional interrupt to be generated. The interrupt can be used to reprogram the base address when generating double-buffered video.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:02	R/W	LCDUPBASE	0x00000000	**LCD upper panel base address** Starting address of the upper panel frame data in memory; the address is word-aligned.
D01:00	N/A	Reserved	N/A	N/A

Table 371: LCDUPBASE register



Register bit assignment

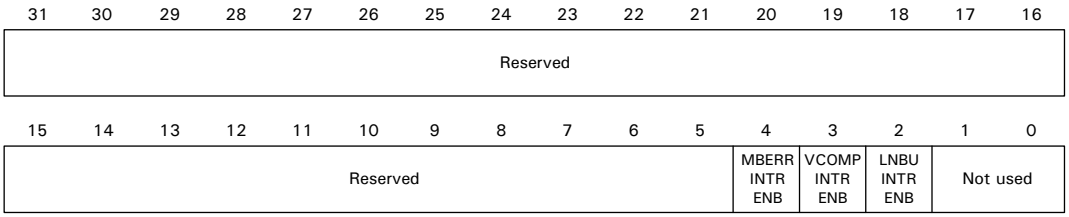
Bits	Access	Mnemonic	Reset	Description
D31:02	R/W	LCDLPBASE	0x00000000	**LCD lower panel base address** Starting address of the lower panel frame data in memory; the address is word-aligned.
D01:00	R/W	Not used	0x0	Read as 0.

Table 372: LCDLPBASE register

LCDINTRENABLE

Address: A080 0018

LCDINTRENABLE is the interrupt enable register. Setting bits within this register enables the corresponding raw interrupt LCDStatus bits to cause an interrupt to the system.



Register bit assignment

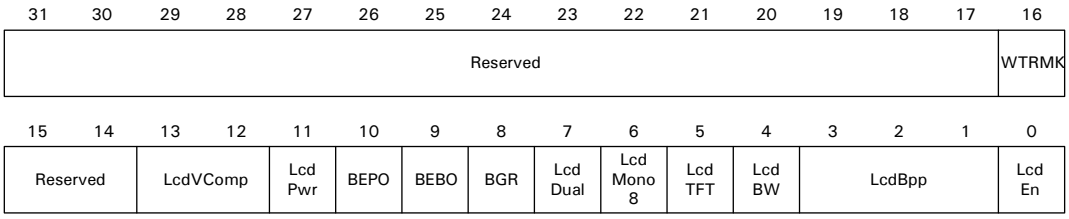
Bits	Access	Mnemonic	Reset	Description
D31:05	N/A	Reserved	N/A	N/A
D04	R/W	MBERRINTRENB	0x0	AHB master bus error interrupt enable.
D03	R/W	VCOMPINTRENB	0x0	Vertical compare interrupt enable.
D02	R/W	LNBUINTRENB	0x0	Next base update interrupt enable.
D01:00	N/A	Not used	0x0	Always write 0.

Table 373: LCDINTRENABLE register

LCDControl register

Address: A080 001C

The LCDControl register controls the mode in which the LCD controller operates.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:17	N/A	Reserved	N/A	N/A

Table 374: LCDControl register

Bits	Access	Mnemonic	Reset	Description
D16	R/W	WATERMARK	0x0	**LCD DMA FIFO watermark level** 0 LCD controller requests AHB bus when either of the DMA FIFOs have at least four empty locations. 1 LCD controller requests AHB bus when either of the DMA FIFOs have at least eight empty locations. (Use this setting for optimum bus bandwidth.)
D15:14	N/A	Reserved	N/A	N/A
D13:12	R/W	LcdVComp	0x0	Generate vertical compare interrupt (VCOMP; see "LCDStatus register" on page 605) at one of the following: 00 Start of vertical synchronization 01 Start of back porch 10 Start of active video 11 Start of front porch
D11	R/W	LcdPwr	0x0	**LCD power enable** 0 Power not gated through to LCD panel and CLD[23:0] signals disabled (held low). 1 Power gated through to LCD panel and CLD[23:0] signals enabled (active). See "LCD power up and power down sequence support" on page 575 for additional information.
D10	R/W	BEPO	0x0	**Big endian pixel ordering within a byte** 0 Little endian pixel ordering within a byte. 1 Big endian pixel ordering within a byte. The BEPO bit selects between Little and Big endian pixel packing for 1, 2, and 4 bpp display modes; the bit has no effect on 8 or 16 bpp pixel formats. See "Pixel serializer" on page 581 for additional information.
D09	R/W	BEBO	0x0	**Big endian byte order** 0 Little endian byte order 1 Big endian byte order

Table 374: LCDControl register

Bits	Access	Mnemonic	Reset	Description
D08	R/W	BGR	0x0	**RGB or BGR format selection** 0 RGB: Normal output 1 BGR: Red and blue swapped
D07	R/W	LcdDual	0x0	**LCD interface is dual panel STN** 0 Single panel LCD is in use. 1 Dual panel LCD is in use.
D06	R/W	LcdMono8	0x0	**Monochrome LCD has 8-bit interface** 0 Mono LCD uses 4-bit interface. 1 Mono LCD uses 8-bit interface. Controls whether monochrome STN LCD uses a 4- or 8-bit parallel interface. Program this bit to 0 for other modes.
D05	R/W	LcdTFT	0x0	**LCD is TFT** 0 LCD is STN display; use grayscaler. 1 LCD is TFT; do *not* use grayscaler.
D04	R/W	LcdBW	0x0	**STN LCD is monochrome (black and white)** 0 STN LCD is color 1 STN LCD is monochrome This bit has no meaning in TFT mode.
D03:01	R/W	LcdBpp	0x00	**LCD bits per pixel** 000 1 bpp 001 2 bpp 010 4 bpp 011 8 bpp 100 16 bpp 101 24 bpp (TFT panel only) 110 Reserved 111 Reserved

Table 374: LCDControl register

Bits	Access	Mnemonic	Reset	Description
D00	R/W	LcdEn	0x0	**LCD controller enable** 0 LCD signals CLLP, CLCP, CLFP, CLAC, and CLLE disabled (held low). 1 LCD signals CLLP, CLCP, CLFP, CLAC, and CLLE enabled (active). See "LCD power up and power down sequence support" on page 575 for more information about LCD power sequencing.

Table 374: LCDControl register

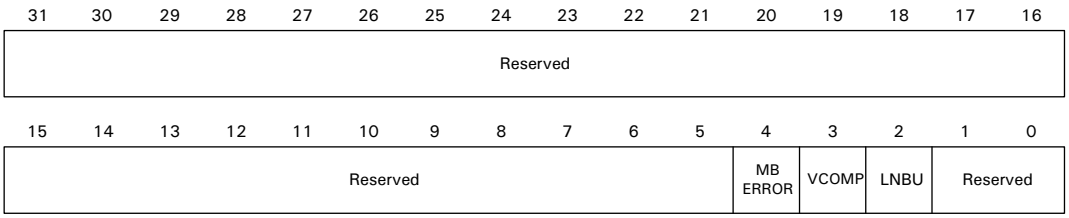
LCDStatus register

Address: A080 0020

The LCDStatus register provides raw interrupt status.

- On a read, the register returns three bits that can generate interrupts when set.
- On writes to the register, a bit value of 1 clears the interrupt corresponding to that bit. Writing a 0 has no effect.

Note: R/C indicates an access of read or clear.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:05	N/A	Reserved	N/A	N/A

Table 375: LCDStatus register

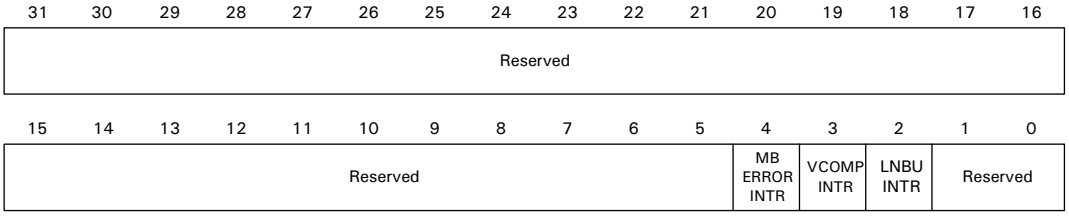
Bits	Access	Mnemonic	Reset	Description
D04	R/C	MBERROR	0x0	**AHB master bus error status** Set when the AHB master encounters a bus error response from a slave.
D03	R/C	VCOMP	0x0	**Vertical compare** Set when one of the four vertical regions, selected by the LCDControl register, is reached. (See LcdVcomp in "LCDControl register" on page 602).
D02	R/C	LNBU	0x0	**LCD next address base update** This bit is mode-dependent, and is set when the current base address registers have been updated successfully by the next address registers. Signifies that a new next address can be loaded if double buffering is in use.
D01:00	N/A	Reserved	0x0	N/A

Table 375: LCDStatus register

LCDInterrupt register

Address: A080 0024

The LCDInterrupt register is a bit-by-bit logical AND of the LCDStatus register and the LCDINTRENABLE register. Interrupt lines correspond to each interrupt. A logical OR of all interrupts is provided to the system interrupt controller.



Register bit assignment

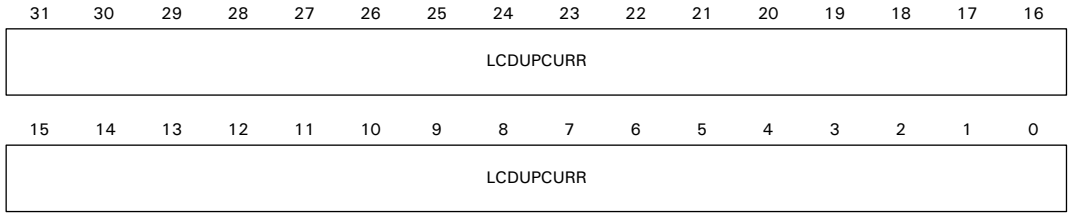
Bits	Access	Mnemonic	Reset	Description
D31:05	N/A	Reserved	N/A	N/A
D04	R	MBERRORINTR	0x0	AHB master bus error interrupt status bit.
D03	R	VCOMPINTR	0x0	Vertical compare interrupt status bit.
D02	R	LNBUINTR	0x0	LCD next base address update interrupt status bit.
D01:00	N/A	Reserved	N/A	N/A

Table 376: LCDInterrupt register

LCDUPCURR and LCDLPCURR

Address: A080 0028 and A080 002C

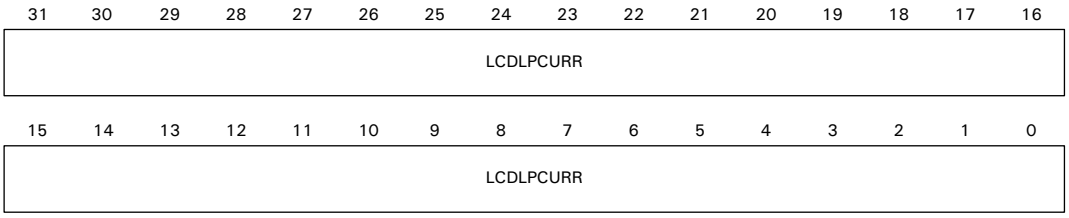
The LCDUPCURR and LCDLPCURR registers contain an approximate value of the upper and lower panel data DMA addresses when read. The registers can change at any time, and therefore can be used only as a mechanism for coarse delay.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:00	R	LCDUPCURR	X	LCD upper panel current address value.

Table 377: LCDUPCURR register



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:00	R	LCDLPCURR	X	LCD lower panel current address value.

Table 378: LCDLPCURR register

LCDPalette register

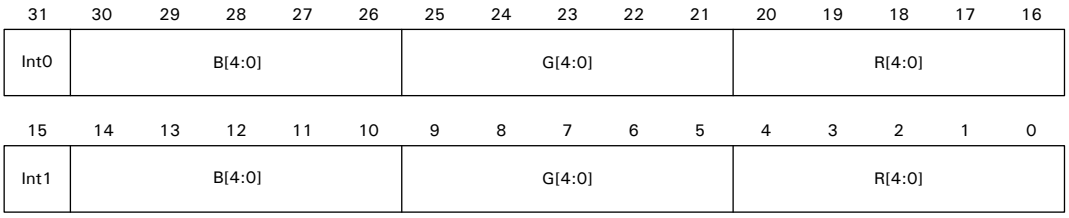
Address A080 0200 – 03FC

LCDPalette registers contain 256 palette entries organized as 128 locations of two entries per word.

Only TFT displays use all of the palette entry bits.

Each word location contains two palette entries, which means that 128 word locations are used for the palette.

- When configured for little endian byte ordering, bits [15:00] are the lower-numbered palette entry and bits [31:16] are the higher-numbered palette entry.
- When configured for big endian byte ordering, bits [31:16] are the lower-numbered palette entry and bits [15:00] are the higher-numbered palette entry.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31	R/W	Int0	N/A	**Intensity/unused** Can be used as the least significant bit of the R, G, and B inputs to a 6:6:6 TFT display, doubling the number of colors to 64K, where each color has two different intensities.
D30:26	R/W	B[4:0]	N/A	**Blue palette data** ■ For STN color displays, only the four most significant bits (04:01) are used. ■ Not used for monochrome displays.
D25:21	R/W	G[4:0]	N/A	**Green palette data** ■ For STN color displays, only the four most significant bits (04:01) are used. ■ Not used for monochrome displays.
D20:16	R/W	R[4:0]	N/A	**Red palette data** ■ For STN color displays, only the four most significant bits (04:01) are used. ■ Used for monochrome displays.
D15	R/W	Int1	N/A	**Intensity bit** Can be used as the least significant bit of the R, G, and B inputs to a 6:6:6 TFT display, doubling the number of colors to 64K, where each color has two different intensities.

Table 379: LCDPalette register

Bits	Access	Mnemonic	Reset	Description
D14:10	R/W	B[4:0]	N/A	**Blue palette data** ■ For STN color displays, only the four most significant bits (04:01) are used. ■ Not used for monochrome displays.
D09:05	R/W	G[4:0]	N/A	**Green palette data** ■ For STN color displays, only the four most significant bits (04:01) are used. ■ Not used for monochrome displays.
D04:00	R/W	R[4:0]	N/A	**Red palette data** ■ For STN color displays, only the four most significant bits (04:01) are used. ■ Used for monochrome displays.

Table 379: LCDPalette register

Interrupts

The LCD controller drives a single interrupt back to the system, from four interrupt sources.

Each of the three individual maskable interrupt sources is enabled or disabled by changing the mask bits in the LCDINTRENABLE register. The status of the individual interrupt sources can be read from the LCDStatus register.

The interrupt sources are described next.

MBERRORINTR — Master bus error interrupt

The master bus error interrupt is asserted when an error response is received by the master interface during a transaction with a slave. When such an error occurs, the master interface enters an error state and remains in this state until the error is cleared (error clearance has been signalled to the master). When the respective interrupt service routine has completed, the master bus error interrupt can be cleared by writing a 1 to the MBERROR bit in the LCDStatus register. This action releases the master interface from its error state to the start of the frame state, allowing a fresh frame of data display to be initiated.

VCOMPINTR — Vertical compare interrupt

The vertical compare interrupt is asserted when one of the four vertical display regions, selected using the LCDControl register, is reached. The interrupt can occur at the beginning of one of the following:

- Vertical synchronization
- Back porch
- Active video
- Front porch

This interrupt can be cleared by writing a 1 to the Vcomp bit in the LCDStatus register.

LBUINTR — Next base address update interrupt

The LCD next base address update interrupt is asserted when either the LCDUPBASE or LCDLPBASE values have been transferred to the LCDUPCURR or LCDLPCURR incrementers (respectively). This tells the system that it is safe to update the LCDUPBASE or LCDLPBASE registers with new frame base addresses, if required.

This interrupt can be cleared by writing a 1 to the LNBU bit in the LCDStatus register.

Serial Control Module: UART

CHAPTER 13

The NS9775 ASIC supports four independent universal asynchronous/synchronous receiver/transmitter channels. Each channel supports several modes, conditions, and formats.

Features

Each channel supports these features:

- DMA transfers to and from system memory
- Independent programmable bit-rate generator
- High speed data transfer: 1.8432 Mbps (asynchronous)
- 32-byte TX FIFO
- 32-Byte RX FIFO
- Programmable data formats
  - 5 to 8 data bits
  - Odd, even, or no parity
  - 1, 2 stop bits
- Programmable channel modes
  - Normal
  - Loopback
  - Remote loopback
  - Control signal support: RTS, CTS, DTR, DSR, DCD, RI
- Maskable interrupt conditions
  - Receive FIFO ready
  - Receive FIFO half full
  - Transmit FIFO ready
  - Transmit FIFO half empty
  - CTS, DSR, DCD, RI state change detection
- Multi-drop capable

Figure 96 shows the structure of the serial module.

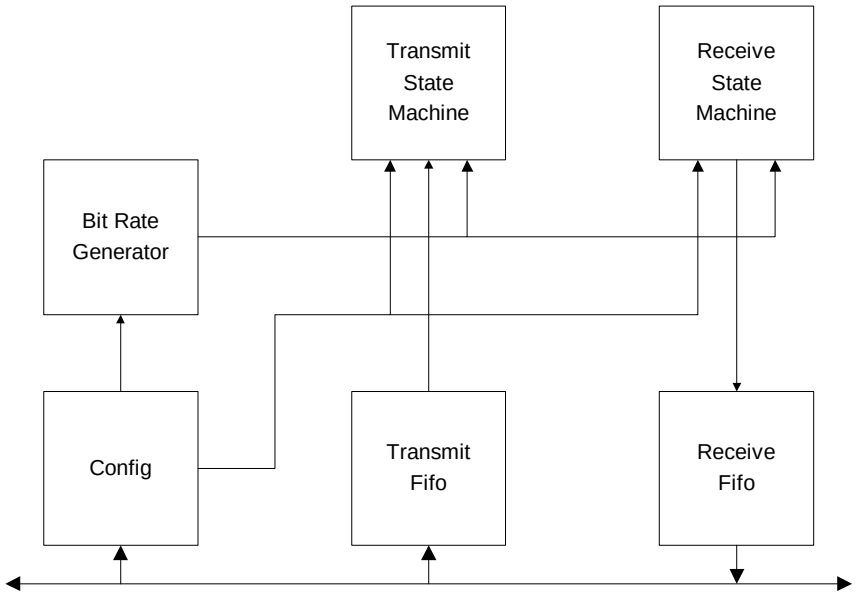


Figure 96: Serial Module structure

Bit-rate generator

Each serial channel supports an independent programmable bit-rate generator. The bit-rate generator runs both the transmitter and receiver of a given channel (there is no split speed support).

You can configure the bit-rate generator to use external clock input or internal system timing as its timing reference. This allows for a wider range of possible bit-rates.

Table 380 describes all possible clock reference sources used by the bit-rate generator.

Name	Description
X1_SYS_OSC/M	The frequency of the external crystal oscillator divided by 2 or 4. ■ The divisor is 2 when the PLLND field in the PLL Configuration register is at least 0x13, producing a nominal frequency of 14.7456 MHz. ■ The divisor is 4 when PLLND is less than 0x13, producing a nominal frequency of 7.3728 MHz. See the System Control Module chapterfor information about the PLL Configuration register.
BCLK	The clock source for all peripherals that are attached to the BBus. The frequency of BCLK is the AHB clock frequency divided by 2.
ExtRxClk	External receive clock on GPIO pins gpio[6], gpio[14], gpio[22], and gpio[26] for serial ports B, A, C, and D, respectively.
ExtTxClk	External transmit clock on GPIO pins gpio[7], gpio[15], gpio[23], and gpio[27] for serial ports B, A, C, and D, respectively.

Table 380: Bit-rate generation clock sources

UART mode

Many applications require a simple mechanism for sending low-speed information between two pieces of equipment. The universal asynchronous/synchronous receiver/transmitter (UART) protocol is the de facto standard for simple serial communications. The protocol does not require sending clock information between the two parties; rather, the UART receiver uses an over-sampling technique to find the bit-level framing of the UART protocol. The UART framing structure is as follows:

```
Start bit: 0
Data bits: 5, 6, 7, or 8
Parity:    Odd, even, or no parity
Stop bits: 1 or 2
```

Because the transmitter and receiver operate asynchronously, there is no need to connect transmit and receive clocks between them. Instead, the receiver over-samples the receive data stream by a factor of 16. During synchronization, the

receiver waits for the start bit. When it finds the high-to-low transition, the receiver counts 8 sample times and uses this point as the bit-center for all remaining bits in the UART frame. Each bit-time is 16 clock ticks apart.

When the UART is not transmitting data, it transmits a continuous stream of ones — referred to as the *IDLE* condition. When data transmission begins, the transmitter sends the start bit and the receiver is enabled.

You can configure the UART to perform the following functions:

- Enable the transmitter using the CTS handshaking signal. In this mode, the transmitter cannot start a new UART data frame unless CTS is active. If CTS is dropped anywhere in the middle of a UART data frame, the current character is completed and the next character is stalled.
- Signal its receiver FIFO status using the RTS handshaking signal. When the receive FIFO has only four characters of available space, the RTS signal is dropped. The RTS and CTS pairs can be used for hardware flow control.

FIFO management

Data flow between a serial controller and memory occurs through the FIFO blocks within each serial controller module. Each serial controller provides both a 32-byte transmit FIFO and a 32-byte receive FIFO. Each FIFO is arranged as eight lines of four bytes to facilitate data transfer across BBus. Both the transmit and receive FIFOs are accessed using the Serial Channel B/A/C/D FIFO registers.

Transmit FIFO interface

The processor can write either 1, 2, 3, or 4 bytes at a time to the transmit FIFO. The number of bytes written is controlled by the data size defined by the `HSIZE` field on the AMBA AHB bus.

- When the system is configured to operate in big endian mode, the most significant bytes in the word written to the FIFO are transmitted first. For example, the long word `0x11223344` results in the character `0x11` being transmitted first, and `0x44` being transmitted last.

- When the system is configured to operate in little endian mode, the least significant bytes in the word written to the FIFO are transmitted first. For example, the long word 0x11223344 results in the character 0x44 being transmitted first, and 0x11 being transmitted last.

Processor interrupts vs. DMA

The transmit FIFO can be filled using processor interrupts or the DMA controller.

Using processor interrupts

The processor can write one long word (4 bytes) of data to the transmit FIFO when the TRDY field in Serial Channel B/A/C/D Status Register A (see "Serial Channel B/A/C/D Status Register A," beginning on page 630) is active high. If the THALF field in Serial Channel B/A/C/D Status Register A is active high, the processor can write four long words (16 bytes) of data to the transmit FIFO. To facilitate an interrupt when either the TRDY or THALF status bits are active, the processor can set one or both of the corresponding interrupt enables (in "Serial Channel B/A/C/D Control Register A," beginning on page 623).

Using the DMA controller

When using the DMA controller, the processor need not interface with any of the serial port registers for data flow; rather, the processor must interface with the DMA channel registers and DMA buffer descriptor block. To facilitate the use of transmit DMA, the EXTDMA field in Serial Channel B/A/C/D Control Register A must be set active high. When the ETXDMA field is set active high, disable the serial transmitter interrupts.

Receive FIFO interface

The receive FIFO presents up to four bytes of data at a time to the processor interface. The number of valid bytes found in the next read of the FIFO is defined by the information in the RXFDB field (in "Serial Channel B/A/C/D Status Register A" on page 630).

- When the system is configured to operate in big endian mode, the most significant bytes in the word written to the FIFO are read first. For example, the long word 0x11223344 results in the character 0x11 being read first, and 0x44 being read last.

- When the system is configured to operate in little endian mode, the least significant bytes in the word written to the FIFO are read first. For example, the long word `0x11223344` results in the character `0x44` being read first, and `0x11` being read last.

When reading from the receive FIFO, the processor must perform a long word read operation. Each time a read cycle to the receive FIFO is performed, the receive FIFO advances to the next long word entry. The processor cannot read individual bytes from the same FIFO long word entry.

Processor interrupts vs. DMA

The receive FIFO can be emptied using processor interrupts or the DMA controller.

Using processor interrupts

The processor can read one long word (4 bytes) of data from the receive FIFO when the RRDY field (in "Serial Channel B/A/C/D Status Register A" on page 630) is set active high. The long word read may have 1, 2, 3, or 4 bytes of valid data within the word. The number of valid bytes is determined by the bit encoding in the RXFDB field in Serial Channel B/A/C/D Status Register A. The RXFDB field must be read before the FIFO Data register is read.

The RBC bit in Serial Channel B/A/C/D Status Register A indicates that a receive data buffer has been closed and receiver status can be read from this register. Before additional data can be read from the FIFO, the RBC bit must be acknowledged by writing a 1 to the same bit position in Serial Channel B/A/C/D Status Register A.

These steps provide the recommended process flow for the serial port receiver interrupt service routine:

1. Read Serial Channel B/A/C/D Status Register A.
2. If RRDY is true:
   a. Read the data FIFO.
   b. Use the RXFDB field to pick out valid bytes.
3. If RBC is true:
   a. Record receiver buffer closed status (if you want to).
   b. Write a 1 to the RBC bit position in Serial Channel B/A/C/D Status register A.
   c. Read Serial Channel B/A/C/D Status Register A again.

To facilitate an interrupt when either the RRDY or RBC status bits are active, the processor must set one or both of the corresponding interrupt enables in Serial Channel B/A/C/D Control Register A.

Using the DMA controller

When using DMA, the processor need not interface with any of the serial port registers for data flow; rather, the processor must interface with the DMA channel registers and the DMA buffer descriptor block. To facilitate use of transmit DMA, the ERXDMA field in Serial Channel B/A/C/D Control register A must be set active high. When ERXDMA is set active high, disable the serial receiver interrupts.

Serial port performance

The serial ports have a finite performance limit on their ability to handle various serial protocols. The performance is limited by the speed of the SYSCLK operating the NS9775 ASIC. The configured speed for the internal PLL defines the BCLK rate; for UART (x8), the serial port maximum rate is 1834200 baud, for UART (x16), the serial port maximum rate is 921600 baud, and for UART (x32), the serial port maximum rate is 460800 baud.

Serial port control and status registers

All configuration registers must be accessed as 32-bit words and as single accesses only. No bursting is allowed.

The configuration registers for serial controller B are located at 0x9020_0000; the configuration registers for serial controller A are located at 0x9020_0040. Table 381 shows a single, two-channel address map for serial controllers B and A.

Address	Description
9020 0000	Channel B Control Register A
9020 0004	Channel B Control Register B

Table 381: Serial channel B & A configuration registers

Address	Description
9020 0008	Channel B Status Register A
9020 000C	Channel B Bit-Rate register
9020 0010	Channel B FIFO Data register
9020 0014	Channel B Receive Buffer Gap Timer
9020 0018	Channel B Receive Character Gap Timer
9020 001C	Channel B Receive Match register
9020 0020	Channel B Receive Match Mask register
9020 0034	Channel B Flow Control register
9020 0038	Channel B Flow Control Force register
9020 0040	Channel A Control Register A
9020 0044	Channel A Control Register B
9020 0048	Channel A Status Register A
9020 004C	Channel A Bit-Rate register
9020 0050	Channel A FIFO Data register
9020 0054	Channel A Receive Buffer Gap Timer
9020 0058	Channel A Receive Character Gap Timer
9020 005C	Channel A Receive Match register
9020 0060	Channel A Receive Match Mask register
9020 0074	Channel A Flow Control register
9020 0078	Channel A Flow Control Force register

Table 381: Serial channel B & A configuration registers

The configuration registers for serial controller C are located at 0x9030_0000; the configuration registers for serial controller D are located at 0x9030_0040. Table 382 shows a single, two-channel address map for serial controllers C and D.

Address	Description
9030 0000	Channel C Control Register A

Table 382: Serial channel C & D configuration registers

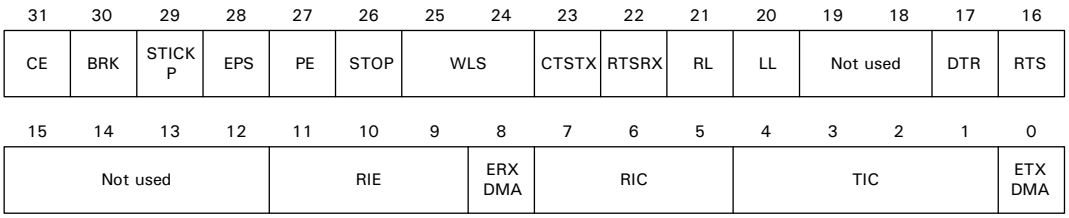
Address	Description
9030 0004	Channel C Control Register B
9030 0008	Channel C Status Register A
9030 000C	Channel C Bit-Rate register
9030 0010	Channel C FIFO Data register
9030 0014	Channel C Receive Buffer Gap Timer
9030 0018	Channel C Receive Character Gap Timer
9030 001C	Channel C Receive Match register
9030 0020	Channel C Receive Match Mask register
9030 0034	Channel C Flow Control register
9030 0038	Channel C Flow Control Force register
9030 0040	Channel D Control Register A
9030 0044	Channel D Control Register B
9030 0048	Channel D Status Register A
9030 004C	Channel D Bit-Rate register
9030 0050	Channel D FIFO Data register
9030 0054	Channel D Receive Buffer Gap Timer
9030 0058	Channel D Receive Character Gap Timer
9030 005C	Channel D Receive Match register
9030 0060	Channel D Receive Match Mask register
9030 0074	Channel D Flow Control register
9030 0078	Channel D Flow Control Force register

Table 382: Serial channel C & D configuration registers

Serial Channel B/A/C/D Control Register A

Address: 9020 0000 / 0040
9030 0000 / 0040

There are two Serial Channel B/A/C/D Control Registers A within each two-channel serial controller module.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31	R/W	CE	0	**Channel enable** 0 Resets the port and the data FIFOs (disables the channel) 1 Enables a serial channel operation The CE field must not be set until all control bits in Serial Channel Control Register A, Control Register B, and Bit-rate register have been defined.
D30	R/W	BRK	0	**Send break** Forces a break condition in UART mode. While BRK is set to 1, the UART transmitter outputs a logic 0 or a space condition on the TXD output signal.
D29	R/W	STICKP	0	**Stick parity** Can be used to force the UART parity field to a certain state as defined by the EPS field (see D28), instead of a parity bit calculated against the data word. STICKP applies only when the PE field (see D27) is also set to 1. Set STICKP to 1 to force transmission of the static parity value.

Table 383: Serial Channel B/A/C/D Control Register A

Bits	Access	Mnemonic	Reset	Description
D28	R/W	EPS	0	**Even parity select** 0 Odd parity 1 Even parity Determines whether the serial channel uses odd or even parity when calculating the parity bit in UART mode. When the STICKP field is set, EPS defines the static state for the parity bit.
D27	R/W	PE	0	**Parity enable** Enables/disables parity generation/checking for the UART transmitter and receiver. The transmitter generates proper parity. The receiver checks for proper parity. If the receiver encounters a bad parity bit, the RPE field is set in the Serial Channel B/A/C/D Status Register A (see page 633).
D26	R/W	STOP	0	**Stop bits** 0 1 stop bit 1 2 stop bits Determines the number of stop bits in each UART transmitter.
D25:24	R/W	WLS	00	**Word length select** 00 5 bits 01 6 bits 10 7 bits 11 8 bits Determines the number of data bits in each UART data word.
D23	R/W	CTSTX	0	**Activate clear to send** Supports hardware handshaking. When CTSTX is set, the transmitter operates only when the external CTS signal is in the active state. An external device, then, can use CTS to temporarily stall data transmission.

Table 383: Serial Channel B/A/C/D Control Register A

Bits	Access	Mnemonic	Reset	Description
D22	R/W	RTSRX	0	**Activate ready to send** Supports hardware handshaking. When RTSRX is set, the RTS output provides the receiver FIFO almost-full condition. When the receiver FIFO backs up, the RTS signal is dropped. The RTS output stalls an external transmitter from delivering data.
D21	R/W	RL	0	**Remote loopback** Provides a remote loopback feature. When RL is set to 1, the TXD transmit output is connected to the RXD receive input. The RL field immediately echoes receive data back as transmit data. This field is used primarily as a test vehicle for external data equipment.
D20	R/W	LL	0	**Local loopback** Provides an internal local loopback feature. When LL is set to 1, the internal receive data stream is connected to the TXD output signal. LL connects the serial channel receiver directly to the serial channel transmitter. This field is used primarily as a test vehicle for the serial channel driver firmware.
D19:18	R/W	Not used	00	This field should be written to 0.
D17	R/W	DTR	0	**Data terminal ready** Controls the state of the external data terminal ready signal. ■ Setting DTR to 1 causes the DTR output to go active. ■ Setting DTR to 0 causes the DTR output to go inactive.
D16	R/W	RTS	0	**Request-to-send** Controls the state of the external request to send signal. ■ Setting RTS to 1 causes the RTS output to go active. ■ Setting RTS to 0 causes the RTS output to go inactive.

Table 383: Serial Channel B/A/C/D Control Register A

Bits	Access	Mnemonic	Reset	Description
D15:12	R/W	Not used	0x0	This field should be written to 0.
D11:09	R/W	RIE	0x00	**Receive interrupt enable** 0 Disables the interrupt 1 Enables the interrupt Allows you to enable interrupts for different receive errors and conditions. [11] Receive register ready [10] Receive FIFO half-full [09] Receive buffer closed
D08	R/W	ERXDMA	0	**Enable receive DMA** Enables the receiver to interact with a DMA channel. The channel is configured to operate in DMA mode when ERXDMA is set to 1. In DMA mode, the DMA controller empties the receive data FIFO and delivers the data to memory. The receive status information from Status Registers B and C are moved automatically to the receive DMA buffer descriptor. This bit is cleared to pause the receiver.
D07:05	R/W	RIC	000	**Receiver interrupt condition** Defines the interrupt enables for a receiver interrupt: [7] Change in DCD interrupt enable [6] Change in RI interrupt enable [5] Change in DSR interrupt enable
D04:01	R/W	TIC	0x0	**Transmitter interrupt condition** Defines the interrupt enables for a transmitter interrupt: [4] Change in CTS interrupt enable [3] Transmit register empty interrupt enable [2] Transmit FIFO half-empty interrupt enable [1] Transmit buffer closed interrupt enable

Table 383: Serial Channel B/A/C/D Control Register A

Bits	Access	Mnemonic	Reset	Description
D00	R/W	ETXDMA	0	**Enable transmit DMA** Enables the transmitter to interact with a DMA channel. The channel is configured to operate in DMA mode when ETXDMA is set to 1. In DMA mode, the DMA controller loads the transmit data FIFO from memory. The transmit status information from Status Register C is moved automatically to the transmit DMA buffer descriptor. This bit is cleared to pause the transmitter.

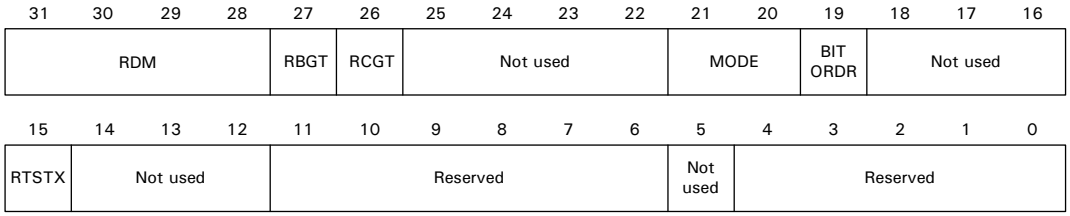
Table 383: Serial Channel B/A/C/D Control Register A

Serial Channel B/A/C/D Control Register B

Address: 9020 0004 / 0044

9030 0004 / 0044

There are two Serial Channel B/A/C/D Control Registers B within each two-channel serial controller module.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:28	R/W	RDM	0x0	**Enable receive data match** [31] RDM1 [30] RDM2 [29] RDM3 [28] RDM4 Enables the receive data match comparators. A receive data match comparison detection can be used to close the current receive buffer descriptor. The last byte in the current receive data buffer contains the match character. Each of these bits enables the respective byte found in the Receive Match register.
D27	R/W	RBGT	0	**Receive buffer GAP timer** Detects the maximum allowed time from when the first byte is placed into the receive data buffer and when the receive data buffer is closed. When RBGT is set to 1, the BGAP field in Serial Channel B/A/C/D Status Register A is set when the timeout value defined in the Receive Buffer GAP Timer register has expired.
D26	R/W	RCGT	0	**Receive character GAP timer** Detects the maximum allowed time from when the last byte is placed into the receive data buffer and when the data buffer is closed. When RCGT is set to 1, the CGAP field in Serial Channel B/A/C/D Status Register A is set when the timeout value defined in the Receive Character GAP Timer register has expired.
D25:22	R/W	Not used	0	Must be written as 0.

Table 384: Serial Channel B/A/C/D Control Register B

Bits	Access	Mnemonic	Reset	Description
D21:20	R/W	MODE	00	**Serial channel mode** 00 UART mode 01 Reserved 10 SPI master mode 11 SPI slave mode Configures the serial channel to operate in UART or SPI mode. The MODE field must be set before the CE bit in Serial Channel B/A/C/D Control Register A is set to 1.
D19	R/W	BITORDR	0	**Bit ordering** 0 Bits are processed LSB first, MSB last 1 Bits are processed MSB first, LSB last Controls the order in which bits are transmitted and received in the Serial Shift register.
D18:16	R/W	Not used	0	Must be written as 0.
D15	R/W	RTSTX	0	**Enable active RTS only while transmitting** Controls the RTS indicator. When RTSTX is set, the RTS output goes active only when the transmitter is actively sending a transmit character. RTSTX allows external hardware to use the RTS signal as a transmit line driver enable signal in multi-drop applications. **Note:** The RTS field in Serial Channel Control Register A must also be set. If the RTSRX field in Serial Channel Control Register A is set, however, do ***not*** set this — the RTSTX — field.
D14:12	R/W	Not used	000	Must be written as 0.
D11:06	N/A	Reserved	N/A	N/A
D05	R/W	Not used	0	Must be written as 0.
D04:00	N/A	Reserved	N/A	N/A

Table 384: Serial Channel B/A/C/D Control Register B

Serial Channel B/A/C/D Status Register A

Address: 9020 0008 / 0048

9030 0008 / 0048

The fields in Serial Channel B/A/C/D Status Register A operate differently when DMA mode is used. Many fields are not required for DMA mode, as they are copied to the status field in the DMA buffer descriptor. See the discussion of the DMA Buffer Descriptor register status field in the BBus DMA Controller chapter.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Match				BGAP	CGAP	Not used				RXFDB		DCD	RI	DSR	CTS
1	2	3	4												

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RBRK	RFE	RPE	ROVER	RRDY	RHALF	RBC	RFS	DCDI	RII	DSRI	CTSI	TRDY	THALF	Not used	T EMPTY

Bits	Access	Mnemonic	Reset	Description
D31:28	R	MATCH	0x0	**Match bit** [31] Match1 [30] Match2 [29] Match3 [28] Match4 Set when a match character in the Receive Match register is configured at the same time that the enable receive data match bit is set in Serial Channel Control Register B (see "RDM" on page 628). The match bit indicates that a data match was found in the receive data stream, and the current receive data buffer has been closed. The last character in the receive data buffer contains the actual match character found. In DMA mode, the MATCH field is copied to bits [15:12] in the DMA buffer descriptor.

Table 385: Serial Channel B/A/C/D Status Register A

Bits	Access	Mnemonic	Reset	Description
D27	R	BGAP	0	**Buffer GAP timer** Set when the receive buffer GAP timer is set in Serial Channel Control Register B (see "RBGT" on page 628) and the timeout value defined in the Receive Buffer GAP Timer register has expired. This bit indicates that the maximum allowed time has passed since the first byte was placed into the receive data buffer. The receive data buffer is closed under this condition. In DMA mode, this field is copied to bit [11] in the DMA buffer descriptor.
D26	R	CGAP	0	**Character GAP timer** Set when the enable receive character GAP timer is set in Serial Channel Control Register B (see "RCGT" on page 628) and the timeout value defined in the Receive Character GAP Timer register (see "Serial Channel B/A/C/D Receive Character GAP Timer" on page 646) has expired. This bit indicates that the maximum allowed time has passed since the previous byte was placed into the receive data buffer. The receive data buffer is closed under this condition. In DMA mode, this field is copied to bit [10] in the DMA buffer descriptor.
25:22	R	Not used	0x0	This field is always read as 0x0.
D21:20	R	RXFDB	00	**Receive FIFO data available** 00 Full word 01 One byte 10 Half word 11 Three bytes This field is valid only when RRDY = 1. Identifies the number of valid bytes contained in the next long word to be read from the Serial Channel FIFO Data register. The next read of the FIFO can contain one, two, three, or four valid bytes of data. This field must be read before the FIFO is read to determine which bytes of the 4-byte long word contain valid data. Normal endian byte ordering rules apply to the Serial Channel FIFO Data register.

Table 385: Serial Channel B/A/C/D Status Register A

Bits	Access	Mnemonic	Reset	Description
D19	R	DCD	0	**Data carrier detect** 0 Inactive 1 Active Indicates the current state of the EIA data carrier detect signal.
D18	R	RI	0	**Ring indicator** 0 Inactive 1 Active Indicates the current state of the EIA ring indicator signal.
D17	R	DSR	0	**Data set ready** 0 Inactive 1 Active Indicates the current state of the EIA data set ready signal.
D16	R	CTS	0	Clear to send 0 Inactive 1 Active Indicates the current state of the EIA clear-to-send signal.
D15	R	RBRK	0	**Receive break condition** Indicates that a receive break condition has been found. The receive data buffer is closed under this condition. In DMA mode, this field is copied to bit [3] in the DMA buffer descriptor.
D14	R	RFE	0	**Receive framing error** Indicates that a receive framing error condition has been found. The receive buffer is closed under this condition. In DMA mode, this field is copied to bit [2] in the DMA buffer descriptor.

Table 385: Serial Channel B/A/C/D Status Register A

Bits	Access	Mnemonic	Reset	Description
D13	R	RPE	0	**Receive parity error** Indicates that a receive parity error has been found. The receive data buffer is closed under this condition. In DMA mode, this field is copied to bit [1] in the DMA buffer descriptor.
D12	R	ROVER	0	**Receive overrun** Indicates that a receive *overrun* error condition has been found. An overrun condition indicates that the FIFO was full while data needed to be written by the receiver. When the FIFO is full, any new receive data is discarded; the contents of the FIFO prior to the overrun condition remain the same. The receive data buffer is closed under this condition. In DMA mode, this field is copied to bit [0] in the DMA buffer descriptor. **Be aware:** The overrun status may not be captured properly in the status FIFO for a serial RX FIFO overrun. if this situation, the overrun condition does not result in a buffer closure and the overrun status bit is not set properly when the receive data is read from the FIFO.

Table 385: Serial Channel B/A/C/D Status Register A

Bits	Access	Mnemonic	Reset	Description
D11	R	RRDY	0	**Receive register ready** Indicates that data is available to be read from the FIFO Data register. Before reading the FIFO Data register, the RXFDB field in this (Serial Channel Status Register A) register (see D21:20) must be read to determine how many active bytes are available during the next read of the FIFO Data register. RRDY typically is used only in interrupt-driven applications; this field is not used for DMA operation. The RRDY status condition can be programmed to generate an interrupt by setting the corresponding IE bit in Serial Channel Control Register A. The RRDY bit is never active when the RBC (D09) bit is active. The RBC bit must be acknowledged by writing a 1 to the same bit position in this register to activate the RRDY bit. When the receiver is configured to operate in DMA mode, hardware automatically handles the interlock between RBC and RRDY.
D10	R	RHALF	0	**Receive FIFO half full** Indicates that the receive data FIFO contains at least 20 bytes (5 lines). RHALF typically is used only in interrupt-driven applications; this field is not used for DMA operation. The RHALF status condition can be programmed to generate an interrupt by setting the corresponding IE bit in Serial Channel Control Register A.

Table 385: Serial Channel B/A/C/D Status Register A

Bits	Access	Mnemonic	Reset	Description
D09	R	RBC	0	**Receive buffer closed** Indicates a receive buffer closed condition. Hardware automatically acknowledges this field when the receiver is configured to operate in DMA mode. The RBC status condition can be programmed to generate an interrupt by setting the corresponding IE bit in Serial Channel Control Register A. While the RBC field is active, the RRDY field is not active. To activate RRDY (to read the data FIFO), the RBC bit must be acknowledged by writing a 1 to the RBC field. This interlock between RBC and RRDY allows the firmware driver to read the status bits in Serial Channel Status Register A or Status Register B. When operating in DMA mode, hardware automatically handles the interlock between RBC and RRDY.
D08	R	RFS	0	**Receive FIFO status** Reflects the current state of the receive FIFO. When set to 1, the receive FIFO has room for only one more line of data.
D07	RW1TC	DCDI	0	**Change in DCD** Indicates a state change in the EIA data carrier detect signal. A 1 indicates that a state change has occurred. This field is asserted only when the corresponding IE bit — RIC field, D[07] — is set to 1 in Serial Channel Control Register A.
D06	R	RII	0	**Change in RI** Indicates a state change in the EIA ring indicator signal. A 1 indicates that a state change has occurred. This field is asserted only when the corresponding IE bit — RIC field, D[06] — is set to 1 in Serial Channel Control Register A.

Table 385: Serial Channel B/A/C/D Status Register A

Bits	Access	Mnemonic	Reset	Description
D05	R	DSRI	0	**Change in DSR** Indicates a state change in the EIA data set ready signal. A 1 indicates that a state change has occurred. This field is asserted only when the corresponding IE bit — RIC field, D[05] — is set to 1 in Serial Channel Control Register A.
D04	R	CTSI	0	**Change in CTS** Indicates a state change in the EIA clear-to-send signal. A 1 indicates that a state change has occurred. This field is asserted only when the corresponding IE bit — TIC field, D[04] — is set to 1 in Serial Channel Control Register A.
D03	R	TRDY	0	**Transmit register empty** Indicates that data can be written to the FIFO Data register. TRDY typically is used only in interrupt-driven applications; this field is not used for DMA operation. The TRDY status condition can be programmed to generate an interrupt by setting the corresponding IE bit in Serial Channel Control Register A.
D02	R	THALF	0	**Transmit FIFO half empty** Indicates that the transmit data FIFO contains room for at least 16 bytes. THALF typically is used only in interrupt-driven applications; this field is not used for DMA operation. The THALF status condition can be programmed to generate an interrupt by setting the corresponding IE bit in Serial Channel Control Register A.
D01	R	Not used	N/A	**Must be written to 0.**
D00	R	TEMPTY	0	**Transmit FIFO empty** Indicates that the transmit data FIFO currently is empty. TEMPTY simply reports the status of the FIFO; this bit does not indicate that the character currently in the Transmit Shift register has been transmitted.

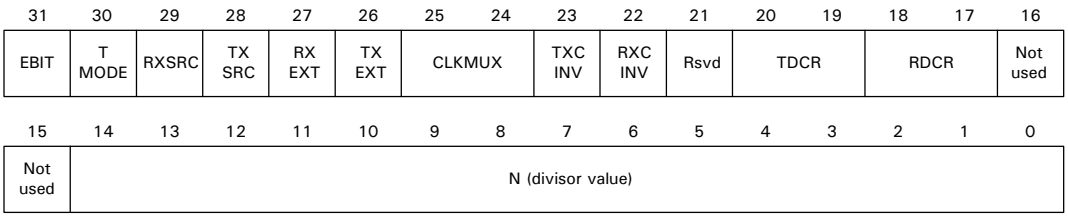
Table 385: Serial Channel B/A/C/D Status Register A

Serial Channel B/A/C/D Bit-rate register

Address: 9020 000C / 004C

9030 000C / 004C

The Serial Channel B/A/C/D Bit-rate register contains the serial channel timing reference control bits and the data rate control bits.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31	R/W	EBIT	0	**Bit-rate generator enable** Enables the internal bit-rate generator when set to 1.
D30	R/W	TMODE	0	**Timing mode** Must be set to 1. Use the additional timing configuration provided by the TDCR and RDCR fields (D[20:19] and D[18:17] in this register) to configure the channel for 1x, 8x, 16x, or 32x mode.
D29	R/W	RXSRC	0	**Receive timing source** 0 Internal 1 External (input using GPIO pin) Controls the source of the receiver clock. The receive clock can be provided by an internal source selected using the RICS field (see D15). As an alternative, the receiver clock can be provided by an input on GPIO pins gpio[6], gpio[14], gpio[22], and gpio[26] for serial ports B, A, C, and D, respectively.

Table 386: Serial Channel B/A/C/D Bit-rate register

Bits	Access	Mnemonic	Reset	Description
D28	R/W	TXSRC	0	**Transmit clock source** 0 Internal 1 External (input using GPIO pin) Controls the source of the transmitter clock. The transmitter clock can be provided by an internal source selected using the TICS field (see D16). As an alternative, the transmitter clock can be provided by an input on GPIO pins gpio[7], gpio[15], gpio[23], and gpio[27] for serial ports B, A, C, and D, respectively.
D27	R/W	RXEXT	0	**Drive receive clock external** 0 Disable 1 Enable Enables the receiver clock to be driven on GPIO pins gpio[6], gpio[14], gpio[22], and gpio[26] for serial ports B, A, C, and D, respectively.'
D26	R/W	TXEXT	0	**Drive transmit clock external** 0 Disable 1 Enable Enables the transmitter clock to be driven on GPIO pins gpio[7], gpio[15], gpio[23], gpio[27] for serial ports B, A, C, and D, respectively.

Table 386: Serial Channel B/A/C/D Bit-rate register

Bits	Access	Mnemonic	Reset	Description
D25:24	R/W	CLKMUX	00	**Bit-rate generator clock source** Controls the bit-rate generator clock source. The bit-rate generator can be configured to use one of four clock sources: 00 `x1_sys_osc/M` (see Table 380, "Bit-rate generation clock sources," on page 616 for more information). This is the recommended setting for standard UART baud rate generation. This selection is not valid when the PLLBP field in the PLL Configuration register is set to 1. 01 BCLK This is the recommended setting for SPI operation. 10 Input clock defined by external receive clock on GPIO pins gpio[6], gpio[14], gpio[22], and gpio[26] for serial ports B, A, C, and D, respectively. 11 Input clock defined by external transmit clock on GPIO pins gpio[7], gpio[15], gpio[23], and gpio[27] for serial ports B, A, C, and D, respectively.
D23	R/W	TXCINV	0	**Transmit clock invert** Controls the relationship between transmit clock and transmit data: ■ When set to 0, transmit data changes relative to the falling edge transition of the transmit clock. ■ When set to 1, transmit data changes relative to the rising edge transition of the transmit clock.

Table 386: Serial Channel B/A/C/D Bit-rate register

Bits	Access	Mnemonic	Reset	Description
D22	R/W	RXCINV	0	**Receive clock invert** Controls the relationship between receive clock and receive data: ■ When set to 0, the receive data input is sampled at the rising edge transition of the receive clock. ■ When set to 1, the receive data input is sampled at the falling edge transition of the receive clock.
D21	N/A	Reserved	N/A	N/A
D20:19	R/W	TDCR	00	**Transmit clock divide rate** 00 Not valid for UART 01 8x clock mode 10 16x clock mode 11 32x clock mode Determines the divide ratio for the transmitter clock.
D18:17	R/W	RDCR	00	**Receive clock divide rate** 00 Not valid for UART 01 8x clock mode 10 16x clock mode 11 32x clock mode Determines the divide ratio for the receiver clock.
D16	R/W	Not used	0	Always write 0 to this field.
D15	R/W	Not used	0	**Always write 0** to this field.

Table 386: Serial Channel B/A/C/D Bit-rate register

Bits	Access	Mnemonic	Reset	Description
D14:00	R/W	N	0x0000	**Divisor value** Defines the divisor value used in the bit-rate generator to determine effective frequency of the bit-rate generator. The divisor value for UART operation is defined as follows: $N = ((F_{CLK} / (UM * BR)) - 1)$ where: ■ F_{CLK} = Determined by CLKMUX field ■ UM = UartMode = 8, 16, or 32 as defined by RDCR and TDCR ■ BR = BaudRate = Required baud rater See Table 387 and Table 388 for examples.

Table 386: Serial Channel B/A/C/D Bit-rate register

The next tables show sample UART baud rates. These rates can be produced using the recommended PLL reference oscillator frequency of 29.4912 MHz and setting the CLKMUX field in the Bit Rate register to 0. The first table shows the range of available baud rates when the PLLND field in the PLL Configuration register is at least 0x13. The second table shows the range of available baud rates when the PLLND field is less then 0x13.

Baud rate	N field		
	x8 UART mode	x16 UART mode	x32 UART mode
75	N/A	12287	6143
150	12287	6143	3071
300	6143	3071	1535
600	3071	1535	767
1200	1535	767	383
2400	767	383	191
4800	383	191	95
7200	255	127	63

Table 387: Bit-rate examples for X1_SYS_OSC/2

Baud rate	N field		
	x8 UART mode	x16 UART mode	x32 UART mode
9600	191	95	47
14400	127	63	31
19200	95	47	23
28800	63	31	15
38400	47	23	11
57600	31	15	7
115200	15	7	3
230400	7	3	1
460800	3	1	0
921600	1	0	N/A
1843200	0	N/A	N/A

Table 387: Bit-rate examples for X1_SYS_OSC/2

Baud rate	N field		
	x8 UART mode	x16 UART mode	x32 UART mode
75	12287	6143	3071
150	6143	3071	1535
300	3071	1535	767
600	1535	767	383
1200	767	383	191
2400	383	191	95
4800	191	95	47
7200	127	63	31
9600	95	47	23
14400	63	31	15

Table 388: Bit-rate examples for X1_SYS_OSC/4

Baud rate	N field		
	x8 UART mode	x16 UART mode	x32 UART mode
19200	47	23	11
28800	31	15	7
38400	23	11	5
57600	15	7	3
115200	7	3	1
230400	3	1	0
460800	1	0	N/A
921600	0	N/A	N/A
1843200	N/A	N/A	N/A

Table 388: Bit-rate examples for X1_SYS_OSC/4

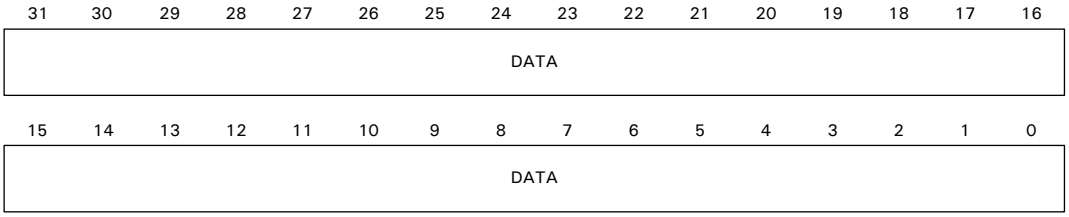
Serial Channel B/A/C/D FIFO Data register

Address: 9020 0010 / 0050
9030 0010 / 0050

The Serial Channel B/A/C/D FIFO Data registers manually interface with the serial controller FIFOs instead of using DMA support.

Writing to the transmit register loads the transmit FIFO. This register can be written only when the TRDY field is set in Serial Channel Status Register A. Writing to the Serial Channel FIFO Data register automatically clears the TRDY bit.

Reading from the receive register empties the receive FIFO. Data is available when the RRDY bit is set in Serial Channel Status Register A. The RXFDB field in Serial Channel Status Register A identifies how many bytes are available to be read. Reading the Serial Channel FIFO Data register automatically clears the RRDY bit in Serial Channel Status Register A.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:00	R/W	DATA	0x00000000	Serial channel FIFO data field.

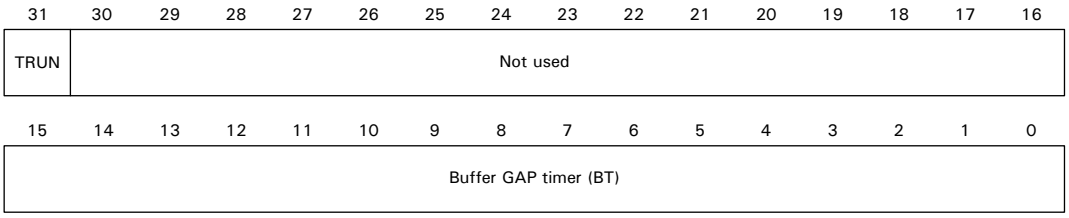
Table 389: Serial Channel B/A/C/D FIFO Data register

Serial Channel B/A/C/D Receive Buffer GAP Timer

Address: 9020 0014 / 0054

9030 0014 / 0054

The Receive Buffer GAP Timer closes out a receive serial data buffer. This timer can be configured to provide an interval in the range of 34.7uS to 2.27 S. The timer is reset when the first character is received in a new buffer. New characters are received while the timer operates; when the timer reaches its programmed threshold, the receive buffer is closed.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31	R/W	TRUN	0	**Buffer GAP timer enable** 0 Disables the timer 1 Enables the timer
D30:16	R/W	Not used	0x0000	Must be written as 0.

Table 390: Serial Channel B/A/C/D Receive Buffer GAP Timer

Bits	Access	Mnemonic	Reset	Description
D15:00	R/W	BT	0x0000	Buffer GAP timer Defines the required value for the receive buffer GAP timer. BT is a function of the channel bit-rate and the receive buffer size. **Recommended approach:** Set the buffer GAP timer to be a value that is slightly larger than the amount of time required to fill the maximum buffer size using the channel bit-rate. Compute the BT value as shown: BT = (((Timeout * F_{CLK}) / 512) - 1) where: ■ F_{CLK} = (x1_sys_osc / M) (see Table 380 for examples) ■ Timeout = Appropriate timeout in seconds Use the following equation to define the recommended buffer GAP timeout value. Timeout = (((BufferSize + 1) * 8) / DataRate) where: ■ BufferSize = receive buffer size in bytes ■ DataRate = interface data rate in bits

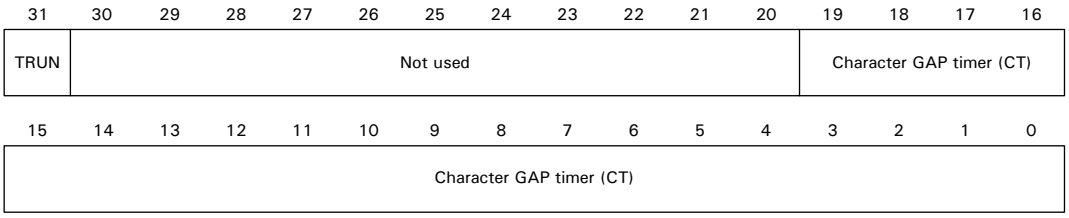
Table 390: Serial Channel B/A/C/D Receive Buffer GAP Timer

Serial Channel B/A/C/D Receive Character GAP Timer

Address: 9020 0018 / 0058

9030 0018 / 0058

The receive character GAP timer closes out a receive serial data buffer due to a gap between characters. This timer is configured to provide an interval in the range of 0.27us to 0.28S. The timer is reset when a character is received. When the timer reaches its programmed threshold, the receive data buffer is closed.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31	R/W	TRUN	0x0	**Character GAP timer enable** 0 Disables the timer 1 Enables the timer
D30:20	R/W	Not used	0x000	Must be written as 0.

Table 391: Serial Channel B/A/C/D Receive Character GAP Timer

Bits	Access	Mnemonic	Reset	Description
D19:00	CT	CT	0x00000	**Character GAP timer** Defines the required value for the receive character GAP timer. Compute the CT value as shown: CT = (((Timeout * F_{CLK})/4) - 1 where: ■ F_{CLK} = (x1_sys_osc / M) (see Table 380 for examples) ■ Timeout = Appropriate timeout in seconds Use the following equation to define the recommended character GAP timeout value: Timeout = (NumBitGap / DataRate) where: ■ NumBitGap = The number of bits in a character plus any start, stop, or parity bits. ■ DataRate = Interface data rate in bits per second. **Note:** When PLL is bypassed, F_{CLK} equals BCLK which equals x1_sys_osc/8. In most designs BCLK = (398.1312Mhz / 8) = 49.7664 Mhz. Examples: Timeout = 0.1ms ; CT field = 0x004DB Timeout = 1.0ms ; CT field = 0x03098 Timeout = 5.0ms ; CT field = 0x0F2FF The maximum value that can be programmed into the CT field is 0x7FFFF.

Table 391: Serial Channel B/A/C/D Receive Character GAP Timer

Serial Channel B/A/C/D Receive Match register

Address: 9020 001C / 005C

9030 001C / 005C

The Serial Channel B/A/C/D Receive Match register contains the four receive data match bytes used in UART mode.

Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:24	R/W	RDMB1	0x00	Receive data match byte1
D23:16	R/W	RDMB2	0x00	Receive data match byte2
D15:08	R/W	RDMB3	0x00	Receive data match byte3
D07:00	R/W	RDMB4	0x00	Receive data match byte4

Table 392: Serial Channel B/A/C/D Receive Match register

Serial Channel B/A/C/D Receive Match MASK register

Address: 9020 0020 / 0060
9030 0020 / 0060

The Serial Channel B/A/C/D Receive Match MASK register contains the four receive match mask bytes that specify which bits in the Receive Match Data register should not be included in the match comparison. To mask a bit in the match comparison function, place a 1 in the same bit position in this register.

Register bit assignment

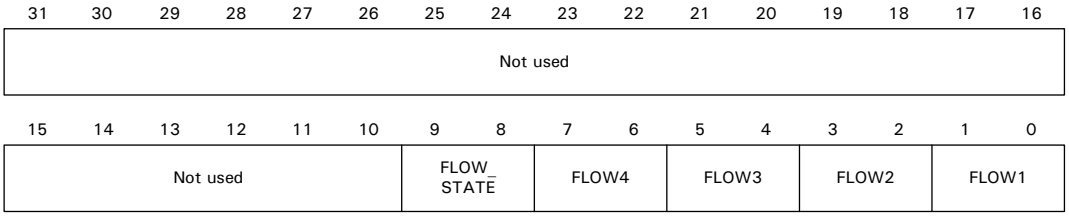
Bits	Access	Mnemonic	Reset	Description
D31:24	R/W	RMMB1	0x00	Receive mask match byte1
23:16	R/W	RMMB2	0x00	Receive mask match byte2
15:08	R/W	RMMB3	0x00	Receive mask match byte3
07:00	R/W	RMMB4	0x00	Receive mask match byte4

Table 393: Serial Channel B/A/C/D Receive Match MASK register

Serial Channel B/A/C/D Flow Control register

Address: 9020 0034 / 0074
9030 0034 / 0074

The Serial Channel B/A/C/D Flow Control register allows you to define the flow control operation of the serial controller.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:10	R	Not used	0x000000	Always read as0x000000.

Table 394: Serial Channel B/A/C/D Flow Control register

Bits	Access	Mnemonic	Reset	Description
D09:08	R/W	FLOW_STATE	10	**Flow control state** 00 Software-initiated XON 01 Software-initiated XOFF 10 Hardware-initiated XON 11 Hardware-initiated XOFF Defines the current state of the flow control logic.
D07:06	R/W	FLOW4	10	**Flow control enable** 00 Disabled 01 Disabled 10 Change field FLOW_STATE to XON upon match 11 Change field FLOW_STATE to XOFF upon match Allows you to define the flow control characteristics using fields RDMB4 (see "RDMB4" on page 649) and RMMB4 (see "RMMB4" on page 650).
D05:04	R/W	FLOW3	10	**Flow control enable** 00 Disabled 01 Disabled 10 Change field FLOW_STATE to XON upon match 11 Change field FLOW_STATE to XOFF upon match Allows you to define the flow control characteristics using fields RDMB3 (see "RDMB3" on page 649) and RMMB3 (see "RMMB3" on page 650).

Table 394: Serial Channel B/A/C/D Flow Control register

Bits	Access	Mnemonic	Reset	Description
D03:02	R/W	FLOW2	10	**Flow control enable** 00 Disabled 01 Disabled 10 Change field FLOW_STATE to XON upon match 11 Change field FLOW_STATE to XOFF upon match Allows you to define the flow control characteristics using fields RDMB2 (see "RDMB2" on page 649) and RMMB2 (see "RMMB2" on page 650).
D01:00	R/W	FLOW1	10	**Flow control enable** 00 Disabled 01 Disabled 10 Change field FLOW_STATE to XON upon match 11 Change field FLOW_STATE to XOFF upon match Allows you to define the flow control characteristics using fields RDMB1 (see "RDMB1" on page 649) and RMMB1 (see "RMMB1" on page 650).

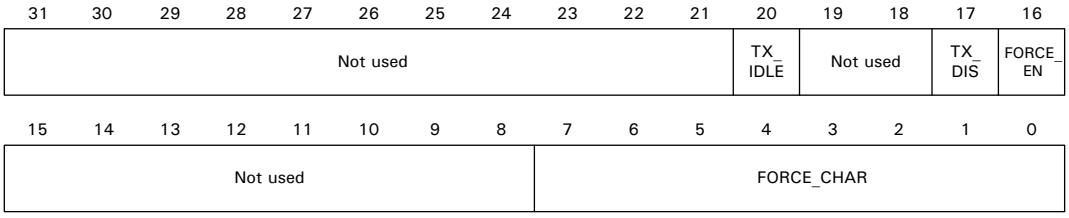
Table 394: Serial Channel B/A/C/D Flow Control register

Serial Channel B/A/C/D Flow Control Force register

Address: 9020 0038 / 0078

9030 0038 / 0078

The Serial Channel B/A/C/D Flow Control Force register allows you to override the normal flow of transmit data.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:21	R	Not used	0x000	Always read as 0x000.
D20	R	TX_IDLE	0	**Transmit idle** Indicates whether the transmit state machine has been forced into an idle state by writing a 1 to the TX_DIS field (see D17).
D19:18	R	Not used	00	Always read as 00.
D17	R/W	TX_DIS	0	**Transmit disable** Allows you to force the transmit state machine into the idle state. If a transmission is in progress, the current byte will complete before the state machine moves into the idle state. Write a 1 to enable this feature.
D16	R/W	FORCE_EN	0	**Force transmit** Allows you to force the transmitter to send the character specified by the FORCE_CHAR (see D07:00) field. All user-specified rules, such as bit order, parity, and number of stop bits, are enforced. Write this field only when TX_IDLE is set to 1. Hardware clears this field once the character has been transmitted. Write a 1 to enable this feature.
D15:08	R	Not used	0x00	Always read as 0x00.
D07:00	R/W	FORCE_ CHAR	0x00	**Force character** Defines the character that is to be forced out of the transmitter.

Table 395: Serial Channel B/A/C/D Flow Control Force register

Serial Control Module: SPI

CHAPTER 14

The NS9775 ASIC supports four independent universal asynchronous/synchronous receiver/transmitter channels. Each channel supports several modes, conditions, and formats.

Features

Each channel supports these features:

- DMA transfers to and from system memory
- Independent programmable bit-rate generator
- High speed data transfer (synchronous)
  - SPI master: 8.33 Mbps
  - SPI slave: 6.25 Mbps
- 32-byte TX FIFO
- 32-Byte RX FIFO

Figure 97 shows the structure of the serial module.

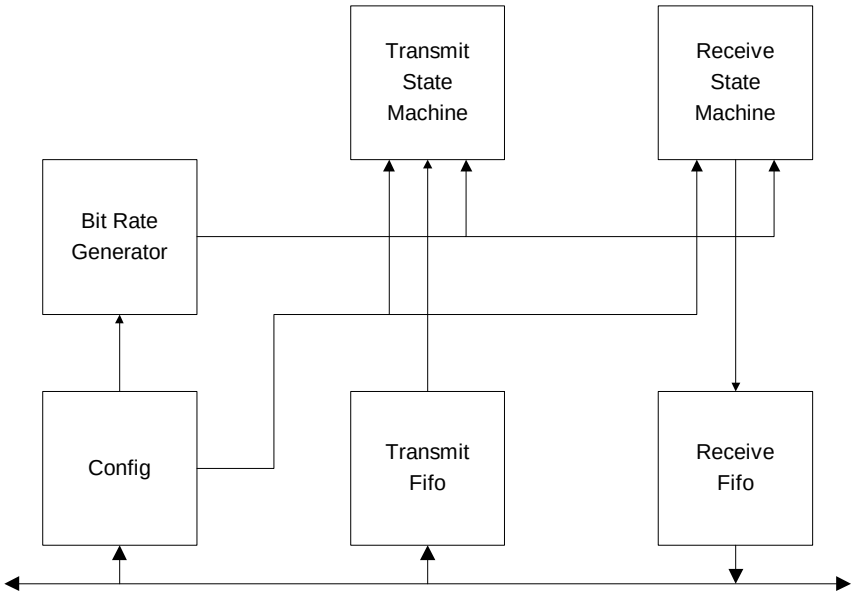


Figure 97: Serial module structure

Bit-rate generator

Each serial channel supports an independent programmable bit-rate generator. The bit-rate generator runs both the transmitter and receiver of a given channel (there is no split speed support).

You can configure the bit-rate generator to use external clock input or internal system timing as its timing reference. This allows for a wider range of possible bit-rates.

Table 396 describes all possible clock reference sources used by the bit-rate generator.

Name	Description
BCLK	The clock source for all peripherals that are attached to the BBus. The frequency of BCLK is the AHB clock frequency divided by 2.
ExtRxClk	External receive clock on GPIO pins gpio[6], gpio[14], gpio[22], and gpio[26] for serial ports B, A, C, and D, respectively.
ExtTxClk	External transmit clock on GPIO pins gpio[7], gpio[15], gpio[23], and gpio[27] for serial ports B, A, C, and D, respectively.

Table 396: Bit-rate generation clock sources

SPI mode

The NS9775 ASIC SPI controller provides these key features:

- Four-wire interface (DATA_OUT, DATA_IN, CLK, ENABLE)
- Master or slave configuration
- Programmable MSB/LSB formatting
- Programmable ENABLE polarity
- Programmable SPI mode (0, 1, 2, 3)

The SPI controller provides a full-duplex, synchronous, character-oriented data channel between master and slave devices, using a four-wire interface (DATA_OUT, DATA_IN, CLK, ENABLE). The master interface operates in a broadcast mode. The slave interface is activated using the ENABLE signal. You can configure the master interface to address various slave interfaces using GPIO pins.

The transmitter and receiver use the same clock. When configured in master mode, the channel's bit-rate generator (see "Bit-rate generator" on page 657) provides the timing reference.

SPI is useful for providing simple parallel/serial data conversion to stream serial data between memory and a peripheral. The SPI port has no protocol associated with it other than that it transfers information in multiples of 8 bits.

The SPI port simultaneously is capable of full duplex operation. The transfer of information is controlled by a single clock signal.

- For the SPI master interface, the clock signal is an output.
- For the SPI slave interface, the clock signal is an input.

The ENABLE signal also qualifies the transfer of information. The SPI ENABLE signal must be active for data transfers to occur, regardless of the SPI clock signal.

SPI modes

The four SPI modes are distinguished by the polarity in which the SPI CLK idles and the SPI CLK data phase used to capture SPI DATA_IN and drive SPI DATA_OUT. Table 397 describes the four modes and the register settings used to select the modes.

	Serial channel B/A/C/D bit rate register settings			Mode functionality		
SPI mode	**SPCPOL**	**TXCINV**	**RXCINV**	**SPI CLK Idle**	**SPI DATA_IN capture edge**	**SPI DATA-OUT drive edge**
0	1	0	0	Low	Rising	Falling
1	0	1	1	High	Falling	Rising
2	1	1	1	Low	Falling	Rising
3	0	0	0	High	Rising	Falling

Table 397: SPI mode definitions

FIFO management

Data flow between a serial controller and memory occurs through the FIFO blocks within each serial controller module. Each serial controller provides both a 32-byte transmit FIFO and a 32-byte receive FIFO. Each FIFO is arranged as eight lines of four bytes to facilitate data transfer across BBus. Both the transmit and receive FIFOs are accessed using the Serial Channel B/A/C/D FIFO registers.

Transmit FIFO interface

The processor can write either 1, 2, 3, or 4 bytes at a time to the transmit FIFO. The number of bytes written is controlled by the data size defined by the `HSIZE` field on the AMBA AHB bus.

- When the system is configured to operate in big endian mode, the most significant bytes in the word written to the FIFO are transmitted first. For example, the long word `0x11223344` results in the character `0x11` being transmitted first, and `0x44` being transmitted last.
- When the system is configured to operate in little endian mode, the least significant bytes in the word written to the FIFO are transmitted first. For example, the long word `0x11223344` results in the character `0x44` being transmitted first, and `0x11` being transmitted last.

Processor interrupts vs. DMA

The transmit FIFO can be filled using processor interrupts or the DMA controller.

Using processor interrupts
The processor can write one long word (4 bytes) of data to the transmit FIFO when the TRDY field in Serial Channel B/A/C/D Status Register A (see "Serial Channel B/A/C/D Status Register A," beginning on page 669) is active high. If the THALF field in Serial Channel B/A/C/D Status Register A is active high, the processor can write four long words (16 bytes) of data to the transmit FIFO. To facilitate an interrupt when either the TRDY or THALF status bits are active, the processor can set one or both of the corresponding interrupt enables (in "Serial Channel B/A/C/D Control Register A," beginning on page 664).

Using the DMA controller
When using the DMA controller, the processor need not interface with any of the serial port registers for data flow; rather, the processor must interface with the DMA channel registers and DMA buffer descriptor block. To facilitate the use of transmit DMA, the EXTDMA field in Serial Channel B/A/C/D Control Register A must be set active high. When the ETXDMA field is set active high, disable the serial transmitter interrupts.

Receive FIFO interface

The receive FIFO presents up to four bytes of data at a time to the processor interface. The number of valid bytes found in the next read of the FIFO is defined by the information in the RXFDB field (in "Serial Channel B/A/C/D Status Register A" on page 669).

- When the system is configured to operate in big endian mode, the most significant bytes in the word written to the FIFO are read first. For example, the long word `0x11223344` results in the character `0x11` being read first, and `0x44` being read last.
- When the system is configured to operate in little endian mode, the least significant bytes in the word written to the FIFO are read first. For example, the long word `0x11223344` results in the character `0x44` being read first, and `0x11` being read last.

When reading from the receive FIFO, the processor must perform a long word read operation. Each time a read cycle to the receive FIFO is performed, the receive FIFO advances to the next long word entry. The processor cannot read individual bytes from the same FIFO long word entry.

Processor interrupts vs. DMA

The receive FIFO can be emptied using processor interrupts or the DMA controller.

Using processor interrupts

The processor can read one long word (4 bytes) of data from the receive FIFO when the RRDY field (in "Serial Channel B/A/C/D Status Register A" on page 669) is set active high. The long word read may have 1, 2, 3, or 4 bytes of valid data within the word. The number of valid bytes is determined by the bit encoding in the RXFDB field in Serial Channel B/A/C/D Status Register A. The RXFDB field must be read before the FIFO Data register is read.

The RBC bit in Serial Channel B/A/C/D Status Register A indicates that a receive data buffer has been closed and receiver status can be read from this register. Before additional data can be read from the FIFO, the RBC bit must be acknowledged by writing a 1 to the same bit position in Serial Channel B/A/C/D Status Register A.

These steps provide the recommended process flow for the serial port receiver interrupt service routine:

1. Read Serial Channel B/A/C/D Status Register A.
2. If RRDY is true:
   a. Read the data FIFO.
   b. Use the RXFDB field to pick out valid bytes.
3. If RBC is true:
   a. Record receiver buffer closed status (if you want to).
   b. Write a 1 to the RBC bit position in Serial Channel B/A/C/D Status register A.
   c. Read Serial Channel B/A/C/D Status Register A again.

To facilitate an interrupt when either the RRDY or RBC status bits are active, the processor must set one or both of the corresponding interrupt enables in Serial Channel B/A/C/D Control Register A.

Using the DMA controller

When using DMA, the processor need not interface with any of the serial port registers for data flow; rather, the processor must interface with the DMA channel registers and the DMA buffer descriptor block. To facilitate use of transmit DMA, the ERXDMA field in Serial Channel B/A/C/D Control register A must be set active high. When ERXDMA is set active high, disable the serial receiver interrupts.

Serial port performance

The serial ports have a finite performance limit on their ability to handle various serial protocols. The performance is limited by the speed of the SYSCLK operating the NS9775 ASIC. The configured speed for the internal PLL defines the BCLK rate; for SPI, the serial port maximum rate is BCLK/8.

Serial port control and status registers

All configuration registers must be accessed as 32-bit words and as single accesses only. No bursting is allowed.

The configuration registers for serial controller B are located at 0x9020_0000; the configuration registers for serial controller A are located at 0x9020_0040. Table 398 shows a single, two-channel address map for serial controllers B and A.

Address	Description
9020 0000	Channel B Control Register A
9020 0004	Channel B Control Register B
9020 0008	Channel B Status Register A
9020 000C	Channel B Bit-Rate register
9020 0010	Channel B FIFO Data register
9020 0014	Channel B Receive Buffer Gap Timer

Table 398: Serial channel B & A configuration registers

Address	Description
9020 0018	Channel B Receive Character Gap Timer
9020 001C	Channel B Receive Match register
9020 0020	Channel B Receive Match Mask register
9020 0038	Channel B Flow Control Force register
9020 0040	Channel A Control Register A
9020 0044	Channel A Control Register B
9020 0048	Channel A Status Register A
9020 004C	Channel A Bit-Rate register
9020 0050	Channel A FIFO Data register
9020 0054	Channel A Receive Buffer Gap Timer
9020 0058	Channel A Receive Character Gap Timer
9020 005C	Channel A Receive Match register
9020 0060	Channel A Receive Match Mask register
9020 0078	Channel A Flow Control Force register

Table 398: Serial channel B & A configuration registers

The configuration registers for serial controller C are located at 0x9030_0000; the configuration registers for serial controller D are located at 0x9030_0040. Table 399 shows a single, two-channel address map for serial controllers C and D.

Address	Description
9030 0000	Channel C Control Register A
9030 0004	Channel C Control Register B
9030 0008	Channel C Status Register A
9030 000C	Channel C Bit-Rate register
9030 0010	Channel C FIFO Data register
9030 0014	Channel C Receive Buffer Gap Timer
9030 0018	Channel C Receive Character Gap Timer

Table 399: Serial channel C & D configuration registers

Address	Description
9030 001C	Channel C Receive Match register
9030 0020	Channel C Receive Match Mask register
9030 0038	Channel C Flow Control Force register
9030 0040	Channel D Control Register A
9030 0044	Channel D Control Register B
9030 0048	Channel D Status Register A
9030 004C	Channel D Bit-Rate register
9030 0050	Channel D FIFO Data register
9030 0054	Channel D Receive Buffer Gap Timer
9030 0058	Channel D Receive Character Gap Timer
9030 005C	Channel D Receive Match register
9030 0060	Channel D Receive Match Mask register
9030 0078	Channel D Flow Control Force register

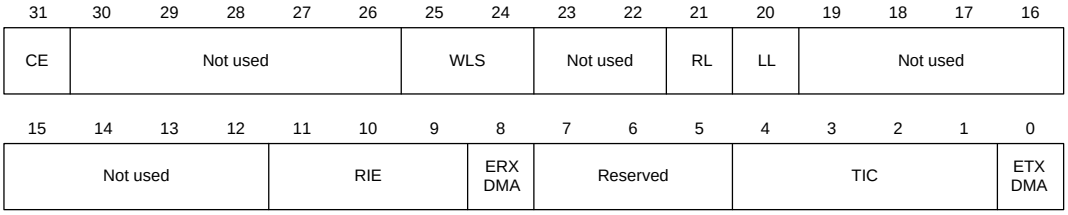
Table 399: Serial channel C & D configuration registers

Serial Channel B/A/C/D Control Register A

Address: 9020 0000 / 0040

9030 0000 / 0040

There are two Serial Channel B/A/C/D Control Registers A within each two-channel serial controller module.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31	R/W	CE	0	**Channel enable** 0 Resets the port and the data FIFOs (disables the channel) 1 Enables a serial channel operation The CE field cannot be set until all control bits in Serial Channel Control Register A, Control Register B, and Bit-rate register are stable.
D30:26	R/W	Not used	0	Always write as 0.
D25:24	R/W	WLS	00	**Word length select** This value must be `2'b11` to select a word length of 8 data bits. SPI mode requires this word length.
D23:22	R/W	Not used		Always write as 0.
D21	R/W	RL	0	**Remote loopback** Provides a remote loopback feature. When RL is set to 1, the TXD transmit output is connected to the RXD receive input. The RL field immediately echoes receive data back as transmit data. This field is used primarily as a test vehicle for external data equipment.
D20	R/W	LL	0	**Local loopback** Provides an internal local loopback feature. When LL is set to 1, the internal receive data stream is connected to the TXD output signal. LL connects the serial channel receiver directly to the serial channel transmitter. This field is used primarily as a test vehicle for the serial channel driver firmware.
D19:12	R/W	Not used	0	This field should be written to 0.

Table 400: Serial Channel B/A/C/D Control Register A

Bits	Access	Mnemonic	Reset	Description
D11:09	R/W	RIE	0x00	**Receive interrupt enable** 0 Disables the interrupt 1 Enables the interrupt Allows you to enable interrupts for different receive errors and conditions. [11] Receive register ready [10] Receive FIFO half-full [09] Receive buffer closed
D08	R/W	ERXDMA	0	**Enable receive DMA** Enables the receiver to interact with a DMA channel. The channel is configured to operate in DMA mode when ERXDMA is set to 1. In DMA mode, the DMA controller empties the receive data FIFO and delivers the data to memory. The receive status information from Status Registers B and C are moved automatically to the receive DMA buffer descriptor. This bit is cleared to pause the receiver.
D07:05	N/A	Reserved	N/A	N/A
D04:01	R/W	TIC	0x0	**Transmitter interrupt condition** Defines the interrupt enables for a transmitter interrupt: [4] Change in CTS interrupt enable [3] Transmit register empty interrupt enable [2] Transmit FIFO half-empty interrupt enable [1] Transmit buffer closed interrupt enable
D00	R/W	ETXDMA	0	**Enable transmit DMA** Enables the transmitter to interact with a DMA channel. The channel is configured to operate in DMA mode when ETXDMA is set to 1. In DMA mode, the DMA controller loads the transmit data FIFO from memory. The transmit status information from Status Register C is moved automatically to the transmit DMA buffer descriptor. This bit is cleared to pause the transmitter.

Table 400: Serial Channel B/A/C/D Control Register A

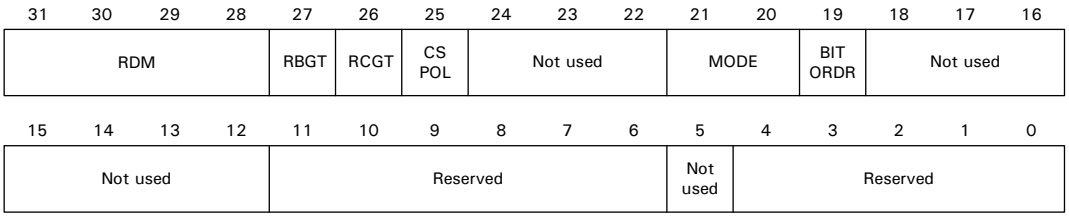
Serial Channel B/A/C/D Control Register B

Address: 9020 0004 / 0044

9030 0004 / 0044

There are two Serial Channel B/A/C/D Control Registers B within each two-channel serial controller module.

Note: The CE field in Serial Channel Control register A should not be set until these control bits are stabilized.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:28	R/W	RDM	0x0	**Enable receive data match** [31] RDM1 [30] RDM2 [29] RDM3 [28] RDM4 Enables the receive data match comparators.
D27	R/W	RBGT	0	**Receive buffer GAP timer** Detects the maximum allowed time from when the first byte is placed into the receive data buffer and when the receive data buffer is closed. When RBGT is set to 1, the BGAP field in Serial Channel B/A/C/D Status Register A is set when the timeout value defined in the Receive Buffer GAP Timer register has expired.

Table 401: Serial Channel B/A/C/D Control Register B

Bits	Access	Mnemonic	Reset	Description
D26	R/W	RCGT	0	**Receive character GAP timer** Detects the maximum allowed time from when the last byte is placed into the receive data buffer and when the data buffer is closed. When RCGT is set to 1, the CGAP field in Serial Channel B/A/C/D Status Register A is set when the timeout value defined in the Receive Character GAP Timer register has expired.
D25	R/W	CSPOL	0	**SPI chip select polarity** 0 Active low chip select 1 Active high chip select Defines the polarity of the SPI chip select signal. **Note:** If you are using SPI slave mode, only a value of 0 is valid; the SPI slave is fixed to an active low chip select. Both values apply to SPI master mode, however.
D24:22	R/W	Not used	0	Must be written as 0.
D21:20	R/W	MODE	00	**Serial channel mode** 00 UART mode 01 Reserved 10 SPI master mode 11 SPI slave mode Configures the serial channel to operate in UART or SPI modes. The MODE field must be set before the CE bit in Serial Channel B/A/C/D Control Register A is set to 1.
D19	R/W	BITORDR	0	**Bit ordering** 0 Bits are processed LSB first, MSB last 1 Bits are processed MSB first, LSB last Controls the order in which bits are transmitted and received in the Serial Shift register.
D18:12	R/W	Not used	0	Always write to 0.
D11:06	N/A	Reserved	N/A	N/A
D05	R/W	Not used	0	Must be written as 0.
D04:00	N/A	Reserved	N/A	N/A

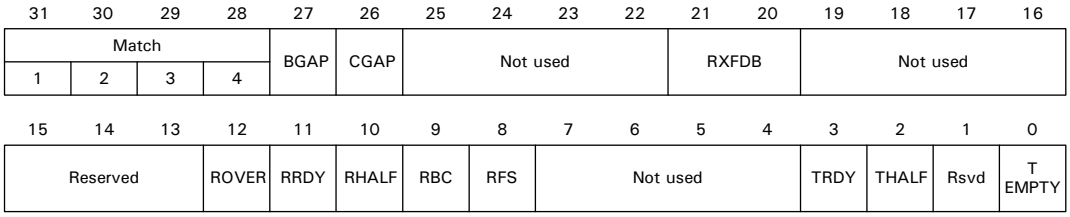
Table 401: Serial Channel B/A/C/D Control Register B

Serial Channel B/A/C/D Status Register A

Address: 9020 0008 / 0048

9030 0008 / 0048

The fields in Serial Channel B/A/C/D Status Register A operate differently when DMA mode is used. Many fields are not required for DMA mode, as they are copied to the status field in the DMA buffer descriptor. See the discussion of the DMA Buffer Descriptor register status field in the BBus DMA Controller chapter.



Bits	Access	Mnemonic	Reset	Description
D31:28	R	MATCH	0x0	**Match bit** [31] Match1 [30] Match2 [29] Match3 [28] Match4 Set when a match character in the Receive Match register is configured at the same time that the enable receive data match bit is set in Serial Channel Control Register B (see "RDM" on page 667). The match bit indicates that a data match was found in the receive data stream, and the current receive data buffer has been closed. The last character in the receive data buffer contains the actual match character found. In DMA mode, the MATCH field is copied to bits [15:12] in the DMA buffer descriptor.

Table 402: Serial Channel B/A/C/D Status Register A

Bits	Access	Mnemonic	Reset	Description
D27	R	BGAP	0	**Buffer GAP timer** Set when the receive buffer GAP timer is set in Serial Channel Control Register B (see "RBGT" on page 667) and the timeout value defined in the Receive Buffer GAP Timer register has expired. This bit indicates that the maximum allowed time has passed since the first byte was placed into the receive data buffer. The receive data buffer is closed under this condition. In DMA mode, this field is copied to bit [11] in the DMA buffer descriptor.
D26	R	CGAP	0	**Character GAP timer** Set when the enable receive character GAP timer is set in Serial Channel Control Register B (see "RCGT" on page 668) and the timeout value defined in the Receive Character GAP Timer register (see "Serial Channel B/A/C/D Receive Character GAP Timer" on page 681) has expired. This bit indicates that the maximum allowed time has passed since the previous byte was placed into the receive data buffer. The receive data buffer is closed under this condition. In DMA mode, this field is copied to bit [10] in the DMA buffer descriptor.
25:22	R	Not used	0x0	This field is always read as 0x0.
D21:20	R	RXFDB	00	**Receive FIFO data available** 00 Full word 01 One byte 10 Half word 11 Three bytes This field is valid only when RRDY = 1. Identifies the number of valid bytes contained in the next long word to be read from the Serial Channel FIFO Data register. The next read of the FIFO can contain one, two, three, or four valid bytes of data. This field must be read before the FIFO is read to determine which bytes of the 4-byte long word contain valid data. Normal endian byte ordering rules apply to the Serial Channel FIFO Data register.

Table 402: Serial Channel B/A/C/D Status Register A

Bits	Access	Mnemonic	Reset	Description
D19:16	R	Not used	0	Always write as 0.
D15:13	N/A	Reserved	N/A	N/A
D12	R	ROVER	0	**Receive overrun** Indicates that a receive *overrun* error condition has been found. An overrun condition indicates that the FIFO was full while data needed to be written by the receiver. When the FIFO is full, any new receive data is discarded; the contents of the FIFO prior to the overrun condition remain the same. The receive data buffer is closed under this condition. In DMA mode, this field is copied to bit [0] in the DMA buffer descriptor. **Be aware:** The overrun status may not be captured properly in the status FIFO for a serial RX FIFO overrun. if this situation, the overrun condition does not result in a buffer closure and the overrun status bit is not set properly when the receive data is read from the FIFO.

Table 402: Serial Channel B/A/C/D Status Register A

Bits	Access	Mnemonic	Reset	Description
D11	R	RRDY	0	**Receive register ready** Indicates that data is available to be read from the FIFO Data register. Before reading the FIFO Data register, the RXFDB field in this (Serial Channel Status Register A) register (see D21:20) must be read to determine how many active bytes are available during the next read of the FIFO Data register. RRDY typically is used only in interrupt-driven applications; this field is not used for DMA operation. The RRDY status condition can be programmed to generate an interrupt by setting the corresponding IE bit in Serial Channel Control Register A. The RRDY bit is never active when the RBC (D09) bit is active. The RBC bit must be acknowledged by writing a 1 to the same bit position in this register to activate the RRDY bit. When the receiver is configured to operate in DMA mode, hardware automatically handles the interlock between RBC and RRDY.
D10	R	RHALF	0	**Receive FIFO half full** Indicates that the receive data FIFO contains at least 20 bytes (5 lines). RHALF typically is used only in interrupt-driven applications; this field is not used for DMA operation. The RHALF status condition can be programmed to generate an interrupt by setting the corresponding IE bit in Serial Channel Control Register A.

Table 402: Serial Channel B/A/C/D Status Register A

Bits	Access	Mnemonic	Reset	Description
D09	R	RBC	0	**Receive buffer closed** Indicates a receive buffer closed condition. Hardware automatically acknowledges this field when the receiver is configured to operate in DMA mode. The RBC status condition can be programmed to generate an interrupt by setting the corresponding IE bit in Serial Channel Control Register A. While the RBC field is active, the RRDY field is not active. To activate RRDY (to read the data FIFO), the RBC bit must be acknowledged by writing a 1 to the RBC field. This interlock between RBC and RRDY allows the firmware driver to read the status bits in Serial Channel Status Register A or Status Register B. When operating in DMA mode, hardware automatically handles the interlock between RBC and RRDY.
D08	R	RFS	0	**Receive FIFO status** Reflects the current state of the receive FIFO. When set to 1, the receive FIFO has room for only one more line of data.
D07:04	R	Not used	0	Always write as 0.
D03	R	TRDY	0	**Transmit register empty** Indicates that data can be written to the FIFO Data register. TRDY typically is used only in interrupt-driven applications; this field is not used for DMA operation. The TRDY status condition can be programmed to generate an interrupt by setting the corresponding IE bit in Serial Channel Control Register A.
D02	R	THALF	0	**Transmit FIFO half empty** Indicates that the transmit data FIFO contains room for at least 16 bytes. THALF typically is used only in interrupt-driven applications; this field is not used for DMA operation. The THALF status condition can be programmed to generate an interrupt by setting the corresponding IE bit in Serial Channel Control Register A.

Table 402: Serial Channel B/A/C/D Status Register A

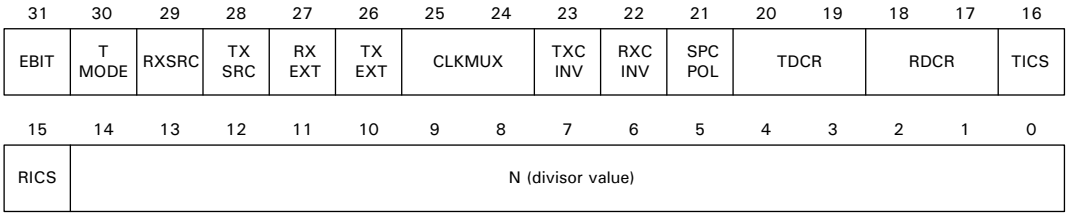
Bits	Access	Mnemonic	Reset	Description
D01	N/A	Reserved	N/A	N/A
D00	R	TEMPTY	0	**Transmit FIFO empty** Indicates that the transmit data FIFO currently is empty. TEMPTY simply reports the status of the FIFO; this bit does not indicate that the character currently in the Transmit Shift register has been transmitted.

Table 402: Serial Channel B/A/C/D Status Register A

Serial Channel B/A/C/D Bit-rate register

Address: 9020 000C / 004C
9030 000C / 004C

The Serial Channel B/A/C/D Bit-rate register contains the serial channel timing reference control bits and the data rate control bits.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31	R/W	EBIT	0	**Bit-rate generator enable** Enables the internal bit-rate generator when set to 1.

Table 403: Serial Channel B/A/C/D Bit-rate register

Bits	Access	Mnemonic	Reset	Description
D30	R/W	TMODE	0	**Timing mode** Must be set to 1. Use the additional timing configuration provided by the TDCR and RDCR fields (D[20:19] and D[18:17] in this register) to configure the channel for 1x, 8x, 16x, or 32x mode.
D29	R/W	RXSRC	0	**Receive timing source** 0 Internal 1 External (input using GPIO pin) Controls the source of the receiver clock. The receive clock can be provided by an internal source selected using the RICS field (see D15). As an alternative, the receiver clock can be provided by an input on GPIO pins gpio[6], gpio[14], gpio[22], and gpio[26] for serial ports B, A, C, and D, respectively. For SPI master and slave, set to 0 for internal.
D28	R/W	TXSRC	0	**Transmit clock source** 0 Internal 1 External (input using GPIO pin) Controls the source of the transmitter clock. The transmitter clock can be provided by an internal source selected using the TICS field (see D16). As an alternative, the transmitter clock can be provided by an input on GPIO pins gpio[7], gpio[15], gpio[23], and gpio[27] for serial ports B, A, C, and D, respectively. For SPI master and slave, set to 0 for internal.
D27	R/W	RXEXT	0	**Drive receive clock external** 0 Disable 1 Enable Enables the receiver clock to be driven on GPIO pins gpio[6], gpio[14], gpio[22], and gpio[26] for serial ports B, A, C, and D, respectively. For SPI master and slave, set to 0 to disable.

Table 403: Serial Channel B/A/C/D Bit-rate register

Bits	Access	Mnemonic	Reset	Description
D26	R/W	TXEXT	0	**Drive transmit clock external** 0 Disable 1 Enable Enables the transmitter clock to be driven on GPIO pins gpio[7], gpio[15], gpio[23], gpio[27] for serial ports B, A, C, and D, respectively. For SPI master mode, set to 1 to enable. For SPI slave mode, set to 0 to disable.
D25:24	R/W	CLKMUX	00	**Bit-rate generator clock source** Controls the bit-rate generator clock source. The bit-rate generator can be configured to use one of four clock sources: 00 x1_sys_osc/M (see Table 396, "Bit-rate generation clock sources," on page 657 for more information). This selection is not valid when the PLLBP field in the PLL Configuration register is set to 1. 01 BCLK This is the recommended setting for SPI master and slave operation. 10 Input clock defined by external receive clock on GPIO pins gpio[6], gpio[14], gpio[22], and gpio[26] for serial ports B, A, C, and D, respectively. 11 Input clock defined by external transmit clock on GPIO pins gpio[7], gpio[15], gpio[23], and gpio[27] for serial ports B, A, C, and D, respectively.
D23	R/W	TXCINV	0	**Transmit clock invert** Controls the relationship between transmit clock and transmit data: ■ When set to 0, transmit data changes relative to the falling edge transition of the transmit clock. Use 0 for SPI modes 0 and 3. ■ When set to 1, transmit data changes relative to the rising edge transition of the transmit clock. Use 1 for SPI modes 1 and 2.

Table 403: Serial Channel B/A/C/D Bit-rate register

Bits	Access	Mnemonic	Reset	Description
D22	R/W	RXCINV	0	**Receive clock invert** Controls the relationship between receive clock and receive data: ■ When set to 0, the receive data input is sampled at the rising edge transition of the receive clock. Use 0 for SPI modes 0 and 3. ■ When set to 1, the receive data input is sampled at the falling edge transition of the receive clock. Use 1 for SPI modes 1 and 2.
D21	R/W	SPCPOL	0/1	**SPI transmit polarity** 0 Idle high operation; use this value for SPI modes 1 and 3 1 Idle low operation; use this value for SPI modes 0 and 2 Defines the idle polarity of the SPI transmit clock.
D20:19	R/W	TDCR	00	**Transmit clock divide rate** 00 1x clock mode (only NRZ or NRZI allowed) 01 8x clock mode 10 16x clock mode 11 32x clock mode Determines the divide ratio for the transmitter clock. If the DPLL is not used, use the 1x clock mode value (00). When DPLL is used in the application, selecting TDCR/RDCR is a function of the transmitter encoding. The NRZ and NRZI modes can use the 1x configuration; all other encoding must use 8x, 16x, or 32x configuration mode. The 8x configuration provides the highest possible data rate; the 32x mode provides the highest possible resolution. The TMODE bit in this register is maintained for NET+Arm family backward compatibility. When setting the TDCR or RDCR register to a non-zero value, the TMODE bit must be set to 1. When TMODE, TDCR, and RDCR are all set to 0, the port defaults to 16x mode of operation.

Table 403: Serial Channel B/A/C/D Bit-rate register

Bits	Access	Mnemonic	Reset	Description
D18:17	R/W	RDCR	00	**Receive clock divide rate** 00 1x clock mode (only NRZ or NRZI allowed) 01 8x clock mode 10 16x clock mode 11 32x clock mode Determines the divide ratio for the receiver clock. If the DPLL is not used, use the 1x clock mode value (00). When the DPLL is used in the application, selecting TDCR/RDCR is a function of the receiver encoding. The NRXZ and NRZI modes can use the 1x configuration; all other encoding must use the 8x, 16x, or 32x configuration mode. The 8x configuration provides the highest possible data rate; the 32x mode provides the highest possible resolution. The TMODE bit in this register is maintained for NET+Arm family backward compatibility. When setting the TDCR or RDCR register to a non-zero value, the TMODE bit must be set to 1.When the TMODE, TDCR, and RDCR fields are all set to 0, the port defaults to the 16x mode of operation.
D16	R/W	TICS	0	**Transmit internal clock source** 0 Transmitter uses the bit-rate generator output for its clock. 1 Transmitter uses the extracted clock provided by DPLL. Defines the transmit clock source when the TXSRC (D28) field is set to 0. There are two sources for internal clocks: the bit-rate generator (BRG) and the receiver digital phase lock loop (DPLL). The bit-rate generator uses a divider mechanism for clock generation. The DPLL extracts the clock from the incoming receive data stream.

Table 403: Serial Channel B/A/C/D Bit-rate register

Bits	Access	Mnemonic	Reset	Description
D15	R/W	RICS	0	**Receive internal clock source** 0 Receiver uses the bit-rate generator output for the clock. 1 Receiver uses the extracted clock provided by the DPLL. Defines the receive clock source when the RXSRC (D29) field is set to 0. There are two sources for internal clocks: the bit-rate generator (BRG) and the receiver digital phase lock loop (DPLL). The bit-rate generator uses a divider mechanism for clock generation. The DPLL extracts the clock from the incoming receive data stream.
D14:00	R/W	N	0x0000	**Divisor value** Defines the divisor value used in the bit-rate generator to determine effective frequency of the bit-rate generator. The divisor value for SPI master (synchronous operation) is defined as follows: $N = ((F_{CLK}/2 * DR) - 1)$ where: ■ FCLK = Determined by CLKMUX field ■ DR = DataRate = Required data rate For SPI slave mode, N is not used. Bit rates is defined by incoming clock edges.

Table 403: Serial Channel B/A/C/D Bit-rate register

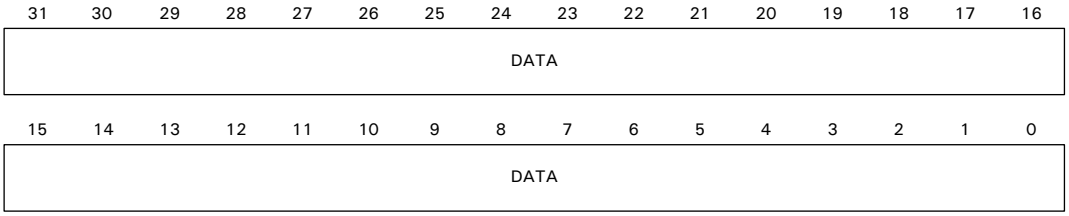
Serial Channel B/A/C/D FIFO Data register

Address: 9020 0010 / 0050
9030 0010 / 0050

The Serial Channel B/A/C/D FIFO Data registers manually interface with the serial controller FIFOs instead of using DMA support.

Writing to the transmit register loads the transmit FIFO. This register can be written only when the TRDY field is set in Serial Channel Status Register A. Writing to the Serial Channel FIFO Data register automatically clears the TRDY bit.

Reading from the receive register empties the receive FIFO. Data is available when the RRDY bit is set in Serial Channel Status Register A. The RXFDB field in Serial Channel Status Register A identifies how many bytes are available to be read. Reading the Serial Channel FIFO Data register automatically clears the RRDY bit in Serial Channel Status Register A.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:00	R/W	DATA	0x00000000	Serial channel FIFO data field.

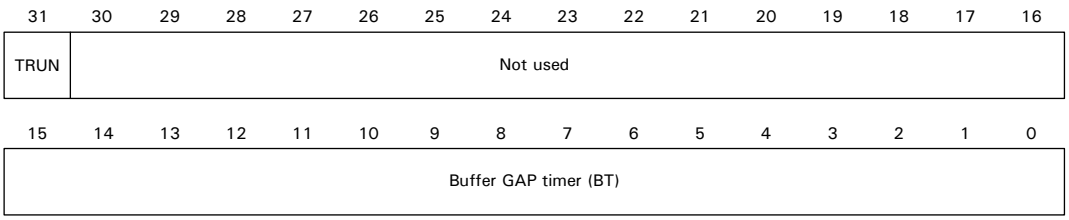
Table 404: Serial Channel B/A/C/D FIFO Data register

Serial Channel B/A/C/D Receive Buffer GAP Timer

Address: 9020 0014 / 0054

9030 0014 / 0054

The Receive Buffer GAP Timer closes out a receive serial data buffer. This timer can be configured to provide an interval in the range of 34.7uS to 2.27 S. The timer is reset when the first character is received in a new buffer. New characters are received while the timer operates; when the timer reaches its programmed threshold, the receive buffer is closed.



Register bit assignment

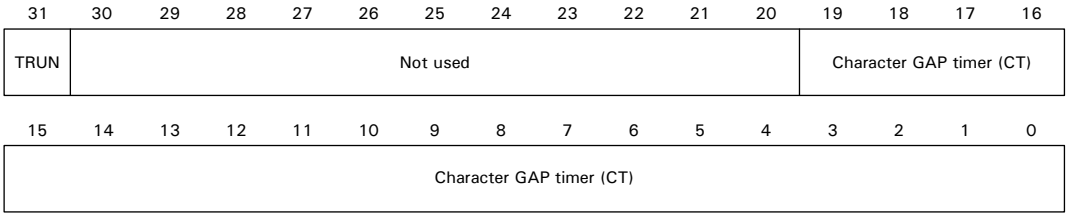
Bits	Access	Mnemonic	Reset	Description
D31	R/W	TRUN	0	**Buffer GAP timer enable** 0 Disables the timer 1 Enables the timer
D30:16	R/W	Not used	0x0000	Must be written as 0.
D15:00	R/W	BT	0x0000	**Buffer GAP timer** Defines the required value for the receive buffer GAP timer. BT is a function of the channel bit-rate and the receive buffer size. **Recommended approach:** Set the buffer GAP timer to be a value that is slightly larger than the amount of time required to fill the maximum buffer size using the channel bit-rate. Compute the BT value as shown: BT = (((Timeout * F_{CLK}) / 512) - 1) where: ■ F_{CLK} = (x1_sys_osc / M) ■ Timeout = Appropriate timeout in seconds Use the following equation to define the recommended buffer GAP timeout value. Timeout = (((BufferSize + 1) * 8) / DataRate) where: ■ BufferSize = receive buffer size in bytes ■ DataRate = interface data rate in bits

Table 405: Serial Channel B/A/C/D Receive Buffer GAP Timer

Serial Channel B/A/C/D Receive Character GAP Timer

Address: 9020 0018 / 0058
9030 0018 / 0058

The receive character GAP timer closes out a receive serial data buffer due to a gap between characters. This timer is configured to provide an interval in the range of 0.27 us to 0.28S. The timer is reset when a character is received. When the timer reaches its programmed threshold, the receive data buffer is closed.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31	R/W	TRUN	0x0	**Character GAP timer enable** 0 Disables the timer 1 Enables the timer
D30:20	R/W	Not used	0x000	Must be written as 0.
D19:00	CT	CT	0x00000	**Character GAP timer** Defines the required value for the receive character GAP timer. Compute the CT value as shown: CT = (((Timeout * F_{CLK})/4) - 1) where: ■ F_{CLK} = (x1_sys_osc / M) ■ Timeout = Appropriate timeout in seconds Use the following equation to define the recommended character GAP timeout value: Timeout = (NumBitGap / DataRate) where: ■ NumBitGap = The number of bits in a character plus any start, stop, or parity bits. ■ DataRate = Interface data rate in bits per second.

Table 406: Serial Channel B/A/C/D Receive Character GAP Timer

Serial Channel B/A/C/D Receive Match register

Address: 9020 001C / 005C

9030 001C / 005C

The Serial Channel B/A/C/D Receive Match register contains the four receive data match bytes used in SPI mode.

Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:24	R/W	RDMB1	0x00	Receive data match byte1
D23:16	R/W	RDMB2	0x00	Receive data match byte2
D15:08	R/W	RDMB3	0x00	Receive data match byte3
D07:00	R/W	RDMB4	0x00	Receive data match byte4

Table 407: Serial Channel B/A/C/D Receive Match register

Serial Channel B/A/C/D Receive Match MASK register

Address: 9020 0020 / 0060
9030 0020 / 0060

The Serial Channel B/A/C/D Receive Match MASK register contains the four receive match mask bytes that specify which bits in the Receive Match Data register should not be included in the match comparison. To mask a bit in the match comparison function, place a 1 in the same bit position in this register.

Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:24	R/W	RMMB1	0x00	Receive mask match byte1
23:16	R/W	RMMB2	0x00	Receive mask match byte2
15:08	R/W	RMMB3	0x00	Receive mask match byte3
07:00	R/W	RMMB4	0x00	Receive mask match byte4

Table 408: Serial Channel B/A/C/D Receive Match MASK register

IEEE 1284 Peripheral Controller

CHAPTER 15

The IEEE 1284 peripheral port supports compatibility mode, nibble mode, byte mode, and ECP mode of operations as a peripheral device. The IEEE 1284 port does not support EPP/mode daisy chain or multiplexer operations.

Requirements

Two components are required to run the IEEE 1284 peripheral-to-host interface:

- **Clock divider.** Required to generate the 1284-port operating clock from the BBus clock. The operating range of the port clock typically is 100 KHz–2 MHz. The clock divider is set using the granularity counter (see "Granularity Count register" on page 718).
- **External transceivers.** The data flow direction control is provided using a `GPIO` pin under software control.

Overview

Figure 98 shows the block diagram of the IEEE 1284 peripheral port control module.

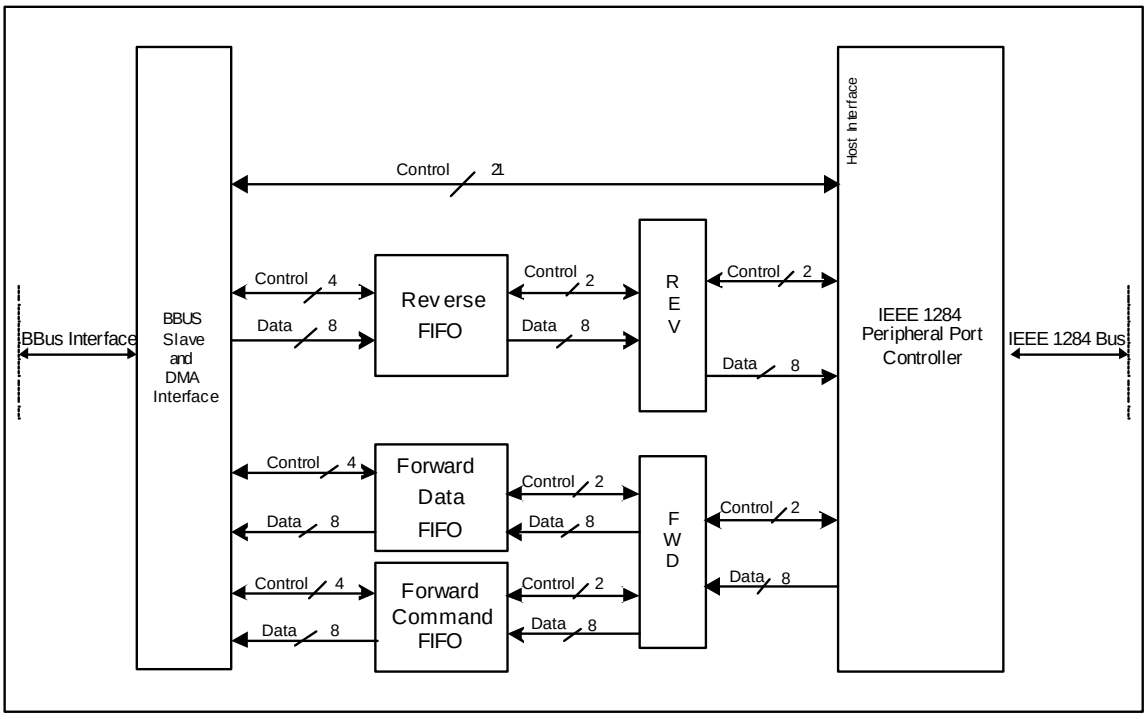


Figure 98: IEEE 1284 peripheral port control module

Note: Traffic direction in the IEEE 1284 is classified as either forward or reverse. The forward direction is equivalent to NS9775 receive. Similarly, the reverse direction is equivalent to NS9775 transmit.

Compatibility mode

Compatibility mode is the standard parallel port (SPP) forward transmission mode (from the host), also known as the *Centronics* mode. The incoming data is routed into the FORWARD DATA IN FIFO, an acknowledge signal is generated by the 1284 peripheral, and DMA requests are issued to the BBus until the FORWARD DATA IN FIFO is empty.

Figure 99 shows the timing relationship on the port interface.

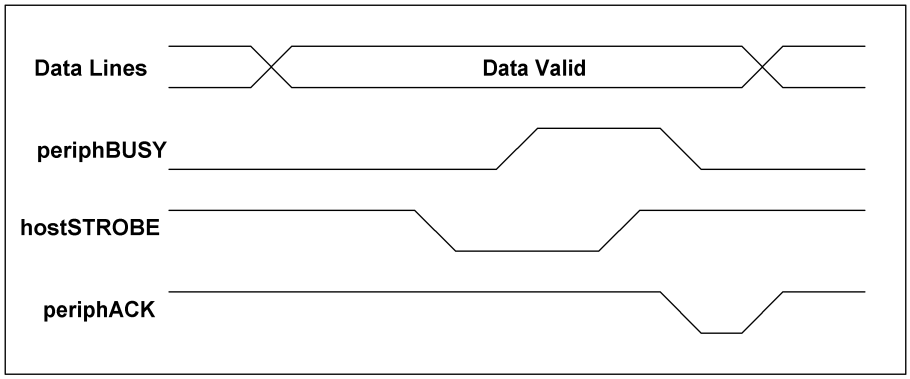


Figure 99: Compatibility mode data transfer cycle

Nibble mode

Nibble mode can send a byte of information to the host by sending two nibbles. This mode operates only in reverse mode.

Figure 100 shows the timing relationship on the port interface.

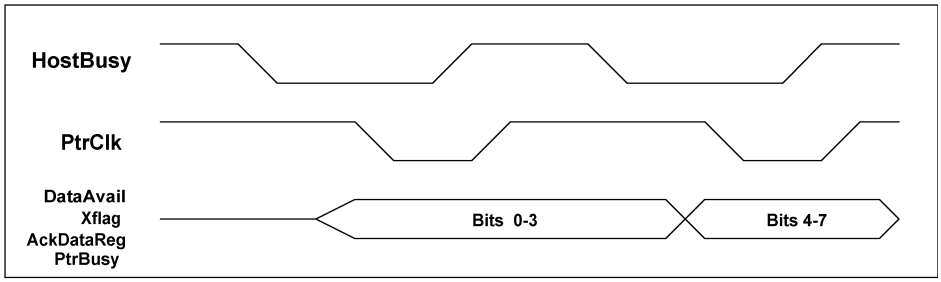


Figure 100: Nibble mode data transfer cycles

Byte mode

Byte mode sends information to the host over the data lines, at 8 bits per cycle. The peripheral sets the PtrClk bit high to acknowledge the host.

Figure 101 shows the timing relationship on the port interface.

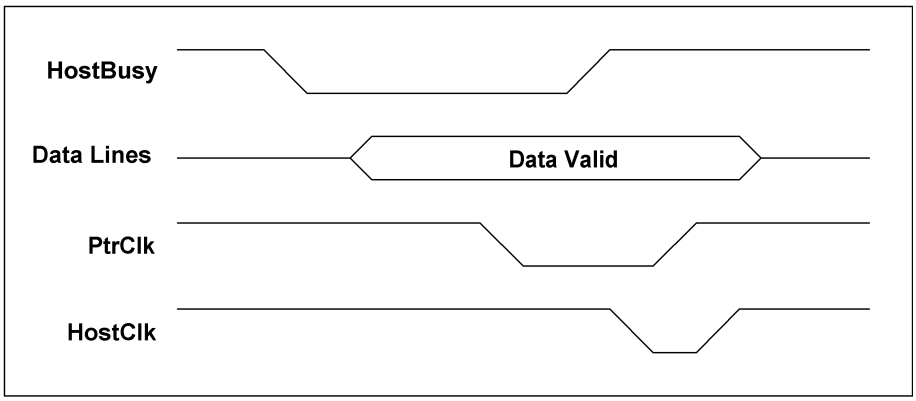


Figure 101: IEEE 1284 byte mode data transfer cycle

ECP mode

ECP (extended capability port) mode provides a high performance bi-directional communication path between the host and the peripheral. The ECP protocol provides two cycle types in both the forward and reverse directions: data cycles and command cycles.

Two types of command cycles are supported by the IEEE peripheral: run length count and channel address. The transfer direction is controlled by the host until a `ReverseRequest` signal is issued by the host. The peripheral can set the `PeriphRequest` signal low to indicate that reverse data is available.

Run_Length_Encoding (RLE) data compression enables real time data compression that can achieve ratios up to 64:1. NS9775 uses RLE decoding to enable large raster images with large strings of identical data to be transferred to system memory.

Forward transfer cycles

Be advised: In forward ECP mode, the `PeriphAck` signal indicates to the host the ability of the peripheral to accept data. At event #6 of the negotiation process, the NS9775 indicates to the host that it cannot accept data and holds its `PeriphAck` signal high for approximately 1200ns.

To differentiate the data cycles from the command cycles, the host sets the HostAck signal at the beginning of the cycle. When HostAck is asserted low, a command cycle is occurring and the data represents either an RLE count or a channel address. Bit 7 of the data byte indicates what is represented:

- If bit 7is 0, the data is an RLE count and (`bits[6:0] + 1`) versions of the subsequent byte are placed into the appropriate forward FIFO based on the value of HostAck while it is being transferred.
- If bit 7 is 1, the data is a channel address (0–127), and bits [6:0] are written into the Forward Address register ("Forward Address register" on page 719).

Figure 102 shows a data cycle followed by a command cycle.

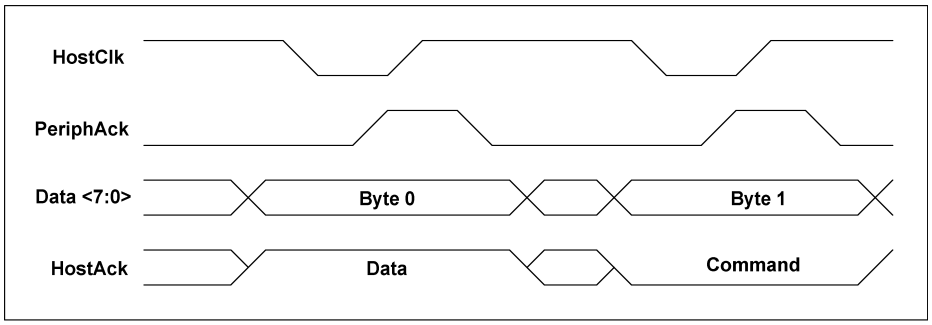


Figure 102: ECP mode forward transfer cycles

▶ **Host processing sequence example:**

1. The host puts the data on the data lines and indicates a data cycle by setting `HostAck` high.
2. The host asserts `HostClk` low to indicate valid data.
3. The peripheral acknowledges the host by setting `PeriphAck` to high.
4. The host sets `HostClk` to high. This edge should be used to latch the data into the peripheral.
5. The peripheral sets `PeriphAck` low, indicating that it's ready for the next data byte.
6. The host sets `HostAck` to low to start the command transfer.

Note: A forward transfer does not have to be a data transfer followed by a command transfer. When `HostClk` is low, the transfer will be data or command depending on whether `HostAck` is high or low.

Reverse transfer cycles

With the ECP protocol, changes in the data direction must be negotiated.

The host must request a reverse channel transfer by asserting the `ReverseRequest` signal. The host waits for the peripheral to acknowledge the request by asserting the `AckReverse` signal. Only then can a reverse channel data transfer take place.

Figure 103 shows a reverse channel data cycle followed by a command cycle. In this case, `PeriphClk` is the data strobe and `HostAck` is the acknowledge signal.

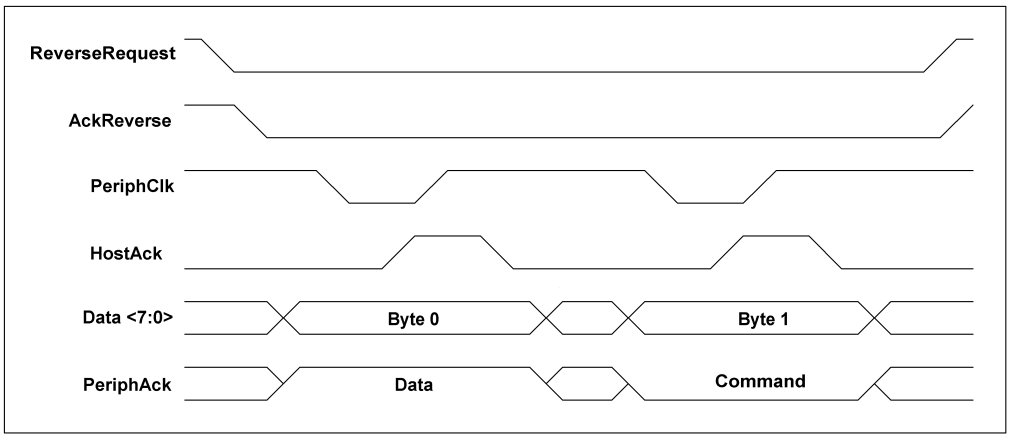


Figure 103: ECP reverse channel transfer cycles

Data and command FIFOs

Separate data and command FIFOs are provided in the forward direction, and a single FIFO is provided in the reverse direction.

These FIFOs can be accessed either through the appropriate DMA channel (see Table 327: "DMA channel assignments" on page 521) or directly by the CPU using access registers provided in this 1284 interface.

- Reading or writing these direct access FIFO registers with DMA control selected results in a bus error.
- Direct access registers, as well as all 1284 registers, use little endian byte ordering, where byte 3 [31:24] is the most significant byte and byte 0 [7:0] is the least significant byte. Before accessing these registers through the CPU, however, you must first indicate the endianness of the AHB to the 1284 peripheral. Do this using the Endian Configuration register in the BBus utility.
- For normal operation, it is recommended that you configure this 1284 interface for DMA control. DMA provides a faster and more efficient interface between IEEE 1284 and the rest of the NS9775. CPU mode is more suitable for diagnostic and testing purposes.

The forward command FIFO is provided solely for the user's benefit, to pass any user-defined, non-IEEE 1284 compliant commands from the host to the NS9775.

Because the NS9775 functions only as a slave, it is not necessary to provide the capability of driving any non-IEEE 1284 compliant commands back to the host.

Important: The 1284 commands are not designed to be stored and passed along. To store a non-IEEE 1284 command in the forward command FIFO, send an RLE command of count one (0x0), followed by the command you want to send. Both bytes must be transferred while HostAck is low and bit[14] of the IEEE 1284 General Configuration register (see page 695) is set to 0.

IEEE 1284 negotiation

The negotiation process is a mechanism by which the host determines the capabilities of the attached peripheral. The module can be programmed to interrupt the software when the host begins negotiation. The module automatically completes negotiation into byte, nibble, and ECP modes. The host uses an extensibility byte to communicate to the module which mode is being negotiated into.

Warning: During a negotiation into either nibble or byte mode, the behavior of the pError signal driven by the NS9775 is out of compliance with the IEEE 1284 standard. The pError signal does not match the value of nFault at event #6 of the negotiation process.

Table 409 defines the extensibility byte values.

Extensibility byte	Definition	Description
1000 0000	Reserved	Reserved
0100 0000	Reserved	Reserved
0011 0000	Request ECP mode with RLE	
0001 0000	Request ECP mode without RLE	
0000 1000	Reserved	Reserved
0000 0100	Request device ID using nibble mode	Receive the device ID a nibble at a time across the status lines.
0000 0101	Request device ID using byte mode	Receive the device ID a byte at a time across the data lines.
0001 0100	Request device ID using ECP mode without RLE	Receive device ID without ECP data compression.

Table 409: Extensibility byte values

Extensibility byte	Definition	Description
0011 0100	Request device ID using ECP mode with RLE	Receive device ID with ECP data compression.
0000 0010	Reserved	Reserved
0000 0001	Byte mode reverse channel transfer	
0000 0000	Nibble mode reverse channel transfer	

Table 409: Extensibility byte values

The NS9775 directly supports RLE compression. The device ID can be returned in any supported reverse channel mode. The device ID is a length field followed by a string of ASCII characters that define the peripheral's characters and/or capabilities.

BBus slave and DMA interface

The BBus slave and DMA interface module controls accesses from the BBus to the IEEE peripheral. The interface can operate in two modes: DMA and CPU.

- In DMA mode, three BBus DMA channels are used for forward data and forward command traffic, and all reverse traffic.
- In CPU mode, the CPU can access the forward data, forward command, and reverse FIFOs directly.

BBus slave and DMA interface register map

The IEEE 1284 module uses the control and status registers listed in Table 410.

All configuration registers must be accessed as 32-bit words and as single accesses only. No bursting is allowed.

Address	Register	Description
9040 0000	GenConfig	General Configuration register

Table 410: 1284 Control and Status registers

Address	Register	Description
9040 0004	InterruptStatusandControl	Interrupt Status and Control register
9040 0008	FIFO Status	FIFO Status register
9040 000C	FwdCmdFifoReadReg	Forward Command FIFO Read register
9040 0010	FwDatFifoReadReg	Forward Data FIFO Read register
9040 0014 – 9040 0018		Reserved
9040 001C	RvFifoWriteReg	Reverse FIFO Write register
9040 0020	RvFifoWriteReg - Last	Reverse FIFO Write Register - Last
9040 0024	FwdCmdDmaControl	Forward Command DMA Control register
9040 0028	FwDatDmaControl	Forward Data DMA Control register
9040 0100 – 9040 017C CSRs (8-bit wide)		
9040 0100	pd	Printer Data Pins register
9040 0104	psr	Port Status register (host)
9040 0108	pcr	Port Control register
9040 010C	pin	Port Status register (peripheral)
9040 0110	Reserved	
9040 0114	fea	Feature Control Register A
9040 0118	feb	Feature Control Register B
9040 011C	fei	Interrupt Enable register
9040 0120	fem	Master Enable register
9040 0124	exr	Extensibility Byte Requested by Host — UART and SPI
9040 0128	ecr	Extended Control register
9040 012C	sti	Interrupt Status register
9040 0130	Reserved	
9040 0134	msk	Pin Interrupt Mask register
9040 0138	pit	Pin Interrupt Control register
9040 013C – 9040 0164		Reserved

Table 410: 1284 Control and Status registers

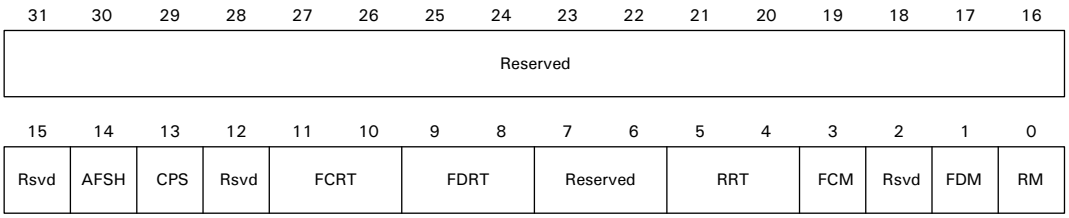
Address	Register	Description
9040 0168	grn	Granularity Count register
9040 016C – 9040 0170		Reserved
9040 0174	eca	Forward Address register
9040 0178	pha	Core Phase register

Table 410: 1284 Control and Status registers

IEEE 1284 General Configuration register

Address: 9040 0000

The IEEE 1284 General Configuration register contains miscellaneous control settings for the IEEE 1284 module.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:15	N/A	Reserved	N/A	N/A
D14	R/W	AFSH	0x0	**HostAck signal handling** 0 `HostAck=1`: Forward data bits 7 to 0 are stored in data FIFO `HostAck=0`: Forward data bits 7 to 0 are stored in command FIFO 1 All forward data bits stored in data FIFO You can use the core interrupt capability to detect transitions on `HostAck`.

Table 411: IEEE 1284 General Configuration register

Bits	Access	Mnemonic	Reset	Description
D13	R/W	CPS	0x0	**Connector *PLH* signal** 0 Indicates to the host that this interface is not ready to operate as an IEEE 1284 slave. 1 Indicates to the host that this interface is ready to operate as an IEEE 1284 slave. This bit should be set by software when the initialization of the 1284 interface is complete.
D12	N/A	Reserved	N/A	N/A
D11:10	R/W	FCRT	0x3	**Forward command ready threshold** (FwCmdReadyThreshold)
D:09:08	R/W	FDRT	0x3	**Forward data ready threshold** (FwDatReadyThreshold) 00 4 bytes 01 8 bytes 10 16 or more bytes 11 28 or more bytes Enables transfer from the corresponding FIFO. DMA is inhibited until the FIFO contains the corresponding number of bytes. Data in the FIFO beneath the threshold is transferred only if the buffer gap timer is used.
D07:06	N/A	Reserved	N/A	N/A
D05:04	R/W	RRT	0x3	**Reverse ready threshold** (RvReadyThreshold) 00 1–4 bytes 01 5–8 bytes 10 13–16 bytes 11 29–32 bytes Enables transfer from the corresponding FIFO. DMA is inhibited until the FIFO can accept the corresponding number of bytes.
D03	R/W	FCM	0x0	**Forward command mode (FwdCmdMode)** 0 Direct CPU access 1 DMA control
D02	NA	Reserved	N/A	N/A

Table 411: IEEE 1284 General Configuration register

Bits	Access	Mnemonic	Reset	Description
D01	R/W	FDM	0x0	**Forward data mode (FwdDataMode)** 0 Direct CPU access 1 DMA control
D00	R/W	RM	0x0	**Reverse mode (RevMode)** 0 Direct CPU access 1 DMA control

Table 411: IEEE 1284 General Configuration register

Interrupt Status and Control register

Address: 9040 0004

The Interrupt Status and Control register contains miscellaneous control settings for the IEEE 1284 module. Bits with an access type of R/C (read/clear) can be set only by hardware, and are cleared by software by writing a 1 to the corresponding bit location. The software is expected to clear the condition causing the interrupt before clearing the interrupt; if the condition is not cleared, the bit and (maskable) interrupt will be reasserted.

Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:27	R	Reserved	0x0	N/A
D26	R/W	RFRIM	0x0	**Reverse FIFO ready interrupt mask** (RvFifoRdyInterruptMask) 0 Mask the interrupt 1 Enable the interrupt

Table 412: Interrupt Status and Control register

Bits	Access	Mnemonic	Reset	Description
D25:24	N/A	Reserved	N/A	N/A
D23	R/W	FDBGM	0x0	**Forward data FIFO byte gap mask** (FwDatFifoByteGapMask) 0 Mask the interrupt 1 Enable the interrupt
D22	R/W	FCBGM	0x0	**Forward command FIFO byte gap mask** (FwCmdFifoByteGapMask) 0 Mask the interrupt 1 Enable the interrupt
D21	R/W	FDMBM	0x0	**Forward data FIFO max buffer mask** (FwDatFifoMaxBufMask) 0 Mask the interrupt 1 Enable the interrupt
D20	R/W	FCMBM	0x0	**Forward command FIFO max buffer mask** (FwCmdFifoMaxBufMask) 0 Mask the interrupt 1 Enable the interrupt
D19	R/W	FDRIM	0x0	**Forward data FIFO ready interrupt mask** (FwDatFifoRdyInterruptMask) 0 Mask the interrupt 1 Enable the interrupt
D18	R/W	FCRIM	0x0	**Forward command FIFO ready interrupt mask** (FwCmdFifoRdyInterruptMask) 0 Mask the interrupt 1 Enable the interrupt
D17	R/W	I1M	0x0	**Peripheral controller interrupt 1 mask** 0 Mask the interrupt 1 Enable the interrupt
D16:11	N/A	Reserved	N/A	N/A
D10	R/C	RFRI	0x1	**Reverse FIFO ready interrupt (RvFifoRdyInterrupt)** Asserted when the reverse FIFO can accept the number of bytes specified in the reverse ready threshold bit in the IEEE 1284 General Configuration register.

Table 412: Interrupt Status and Control register

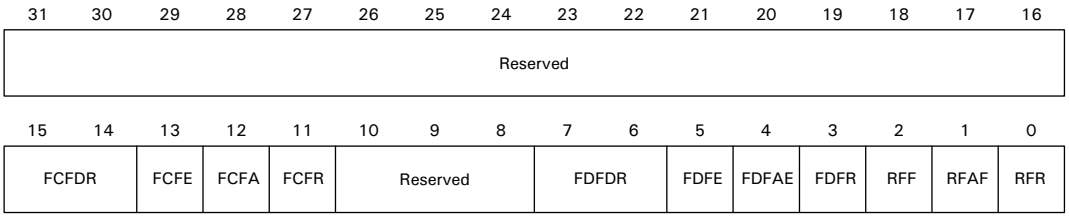
Bits	Access	Mnemonic	Reset	Description
D09	N/A	Reserved	0x1	N/A
D08	N/A	Reserved	0x0	N/A
D07	R/C	FDFBG	0x0	**Forward data FIFO byte gap** (FwDatFifoByteGap) The forward data byte gap timer expired and the buffer closed. Set to 1 to clear this bit.
D06	R/C	FCFBG	0x0	**Forward command FIFO byte gap** (FwCmdFifoByteGap) The forward command byte gap timer expired and the buffer closed. Set to 1 to clear this bit.
D05	R/C	FDFMB	0x0	**Forward data FIFO max buffer** (FwDatFifoMaxBug) The forward data maximum buffer length has been reached and the buffer closed. Set to 1 to clear this bit.
D04	R/C	FCFMB	0x0	**Forward command FIFO max buffer** (FwCmdFifoMaxBuf) The forward command maximum buffer length has been reached and the buffer closed. Set to 1 to clear this bit.
D03	R/C	FDFRI	0x0	**Forward data FIFO ready interrupt** (FwDatFifoRdyInterrupt) Contains data from the host. Set to 1 to clear this bit.
D02	R/C	FCFRI	0x0	**Forward command FIFO ready interrupt** (FwCmdFifoRdyInterrupt) Contains data from the host. Set to 1 to clear this bit.
D01	R/C	PC1I	0x0	**Peripheral controller interrupt 1** Read the peripheral controller Interrupt Status register to determine the source. Set to 1 to clear this bit.
D00	N/A	Reserved	0x1	N/A

Table 412: Interrupt Status and Control register

FIFO Status register

Address: 9040 0008

The FIFO Status register allows the CPU to determine that status of all FIFOs in the 1284 module. You can ignore this register when running the 1284 interface in DMA mode.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:16	N/A	Reserved	N/A	N/A
D15:14	R	FCFDR	0x0	**Forward command FIFO depth remain** (FwCmdFifoDepthRemain) 00 4 bytes 01 1 byte 10 2 bytes 11 3 bytes Determines how many bytes are valid in the current forward command FIFO entry. The current value in the field is not valid if the FIFO is empty.
D13	R	FCFE	0x1	**Forward command FIFO empty** (FwCmdFifoEmpty) 0 FIFO is not empty 1 FIFO is empty
D12	R	FCFA	0x1	**Forward command FIFO almost empty** (FwCmdFifoAlmostEmpty) 0 FIFO has more than 1–4 bytes 1 FIFO has only one 1–4 byte entry This field is not valid if the FIFO is empty.

Table 413: FIFO Status register

Bits	Access	Mnemonic	Reset	Description
D11	R	FCFR	0x0	**Forward command FIFO ready** (FwCmdFifoReady) Asserted if forward command in FIFO is enabled to move data. Determined by FwCmdReadyThreshold (in the IEEE 1284 General Configuration register).
D10:08	N/A	Reserved	N/A	N/A
D07:06	R	FDFDR	0x0	**Forward data FIFO depth remain** (FwDatFifoDepthRemain) 00 4 bytes 01 1 byte 10 2 bytes 11 3 bytes Determines how many bytes are valid in the current forward data FIFO entry. The current value in the field is not valid if the FIFO is empty.
D05	R	FDFE	0x1	**Forward data FIFO empty** (FwDatFifoEmpty) 0 FIFO is not empty 1 FIFO is empty
D04	R	FDFAE	0x0	**Forward data FIFO almost empty** (FwDatFifoAlmostEmpty) 0 FIFO has more than 1–4 bytes 1 FIFO has only one 1–4 byte entry This field is not valid if the FIFO is empty.
D03	R	FDFR	0x0	**Forward data FIFO ready** (FwDatFifoReady) Asserted if forward data in FIFO is enabled to move data. Determined by FwDatReadyThreshold (in the IEEE 1284 General Configuration register).
D02	R	RFF	0x0	**Reverse FIFO full (RvFifoFull)** 0 FIFO is not full 1 FIFO is full

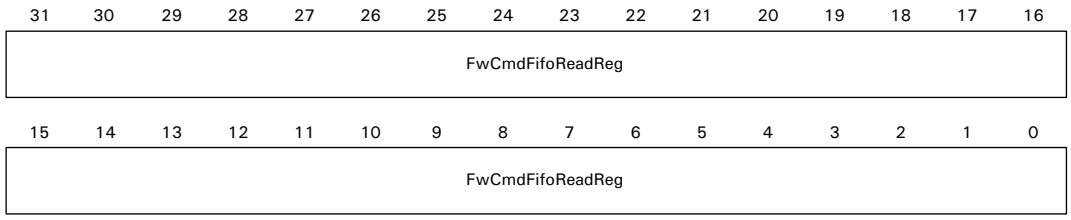
Table 413: FIFO Status register

Bits	Access	Mnemonic	Reset	Description
D01	R	RFAF	0x0	**Reverse FIFO almost full (RvFifoAlmostFull)** 0 FIFO can take more than 1–4 bytes 1 FIFO can take only one 1–4 byte entry This field is not valid id the FIFO is full.
D00	R	RFR	0x0	**Reverse FIFO ready (RvFifoReady)** Asserted if reverse data out FIFO is enabled to move data. Determined by RvDatReadyThreshold (in the IEEE 1284 General Configuration register).

Table 413: FIFO Status register

Forward Command FIFO Read register

Address: 9040 000C



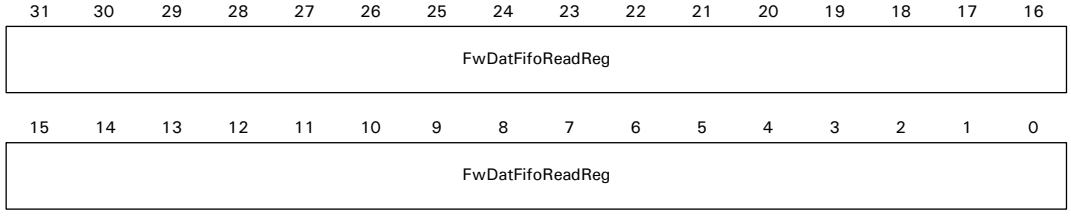
Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:00	R	FwCmdFifoReadReg	N/A	Reads up to four bytes from the Forward Command FIFO when in CPU mode. The CPU must read the FIFO Status register (see page 700) to determine how many bytes are remaining before issuing the read.

Table 414: Forward Command FIFO Read register

Forward Data FIFO Read register

Address: 9040 0010



Register bit assignment

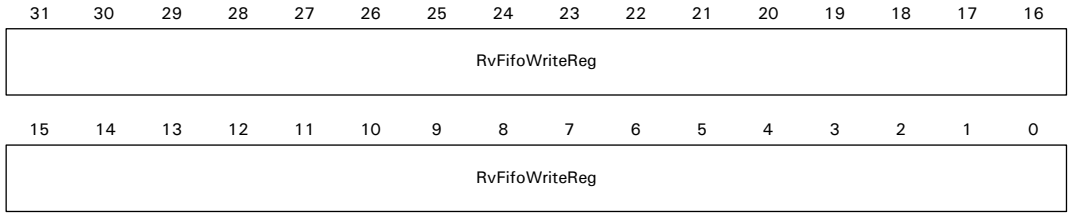
Bits	Access	Mnemonic	Reset	Description
D31:00	R	FwDatFifoReadReg	N/A	Reads up to four bytes from the Forward Data FIFO when in CPU mode. The CPU must read the FIFO Status register (see page 700) to determine how many bytes are remaining before issuing the read.

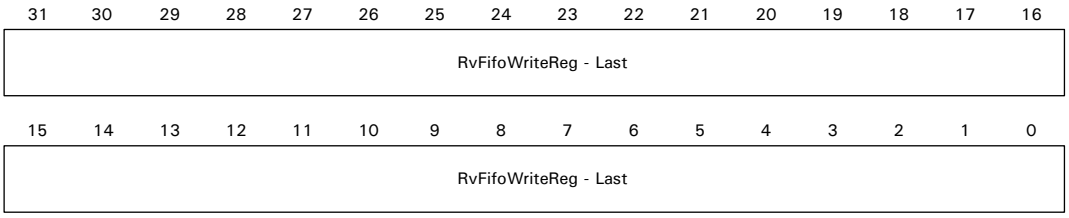
Table 415: Forward Data FIFO Read register

Reverse FIFO Write register/Reverse FIFO Write Register — Last

Address: 9040 001C / 9040 0020

Both registers are 32 bits.





Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:00	W	RvFifoWriteReg	N/A	Write one to four bytes to the Reverse FIFO when in CPU mode. ■ A FIFO entry containing one byte or two bytes is written to Reverse FIFO Write Register — Last. ■ A FIFO entry containing three bytes is written in two steps: Step 1: The lowest 16 bits are written to the Reverse FIFO Register. Step 2: The high byte is written to the Reverse FIFO Write Register — Last. ■ A FIFO entry containing four bytes is written to either register.
D31:00	W	RvFifoWrite Reg — Last	N/A	

Table 416: Reverse Data FIFO Write register/Reverse Data FIFO Write Register — Last

Forward Command DMA Control register

Address: 9040 0024

The Forward Command DMA Control register controls when the Forward command DMA buffer is closed, using two components:

- **16-bit maximum buffer counter.** The maximum buffer counter increments each time a DMA transfer occurs, by the number of bytes in the transfer. The counter is reset each time a DMA is completed. If the counter reaches or exceeds the forward command maximum buffer size (FwCmdMaxBufSize), the 1284 module signals the DMA channel to close the buffer and start a new one. A (maskable) interrupt is generated when FwCmdMaxBufSize is reached. Future bytes are moved using DMA when the next DMA is initiated by the DMA controller.

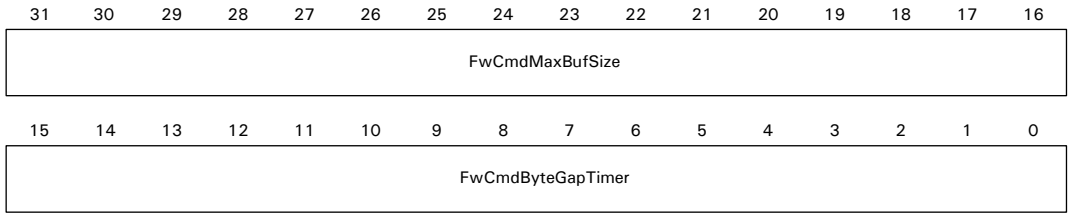
  Note: This counter should not be set to a value greater than the buffer length field value set in the 1284 forward command channel descriptor.

- **16-bit byte gap counter.** The byte gap counter increments on each clock cycle when a byte is not read from the host, with a maximum programmable interval of 1.3 ms based on a 50 MHz BBus clock. The counter is reset when a byte is read from the host. If the counter reaches the forward command byte gap timeout (FwCmdByteGapTimer), the following occurs:

  a Where the FIFOs are written with dwords containing four bytes each, the gap timeout forces an incomplete dword (that is, 1–3 bytes) to be written to the FIFO.

  b Forward command FIFO ready, which usually means the threshold has been met, is asserted. This results in continuation of the currently active DMA until the FIFO is empty.

  c When the data in the FIFO, including the incomplete dwords in Step 1, is output through DMA, the DMA is terminated.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:16	R/W	FwCmdMaxBufSize	0x0	**Forward command maximum buffer size** Maximum buffer size in bytes.
D15:00	R/W	FwCmdByteGapTimer	0x0	**Forward command byte gap timeout** 16-bit byte gap timer in BBus clock cycles.

Table 417: Forward Command DMA Control register

Forward Data DMA Control register

Address: 9040 0028

The Forward Data DMA Control register controls when the forward data DMA buffer is closed, using two components:

- **16-bit maximum buffer counter.** The maximum buffer counter increments each time a DMA transfer occurs, by the number of bytes in the transfer. The counter is reset each time a DMA completes. If the counter reaches or exceeds the forward data maximum buffer size (FwDatMaxBufSize), the 1284 module signals the DMA channel to close the buffer and start a new one. A (maskable) interrupt is generated when FwDatMaxBufSize is reached. Future bytes are moved using DMA when the next DMA is initiated by the DMA controller.

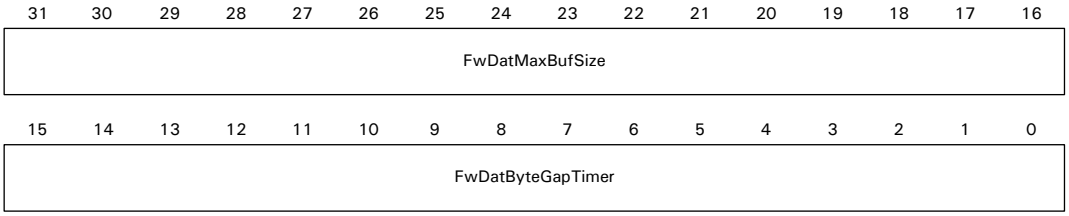
  Note: This counter should not be set to a value greater than the buffer length field value set in the 1284 forward data DMA channel descriptor.

- **16-bit byte gap counter.** The byte gap counter increments on each clock cycle when a byte is not read from the host, with a maximum programmable interval of 1.3 ms based on a 50 MHz BBus clock. The counter is reset when a byte is read from the host. If the counter reaches the forward data byte gap timeout (FwDatByteGapTimer), the following occurs:

  a Where the FIFOs are written with dwords containing four bytes each, the gap timeout forces an incomplete dword (that is, 1–3 bytes) to be written to the FIFO.

b Forward data FIFO ready, which normally means the threshold has been met, is asserted. This results in continuation of the currently active DMA until the FIFO is empty.

c When the data in the FIFO, including the incomplete dwords in Step 1, is output through DMA, the DMA is terminated.



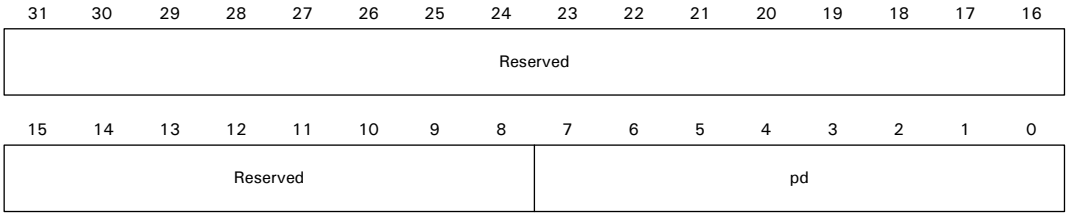
Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:16	R/W	FwDatMaxBufSize	0x0	**Forward data maximum buffer size** Maximum buffer size in bytes.
D15:00	R/W	FwDatByteGapTimer	0x0	**Forward data byte gap timeout** 16-bit byte gap timer in BBus clock cycles.

Table 418: Forward Data DMA Control register

Printer Data Pins register

Address: 9040 0100



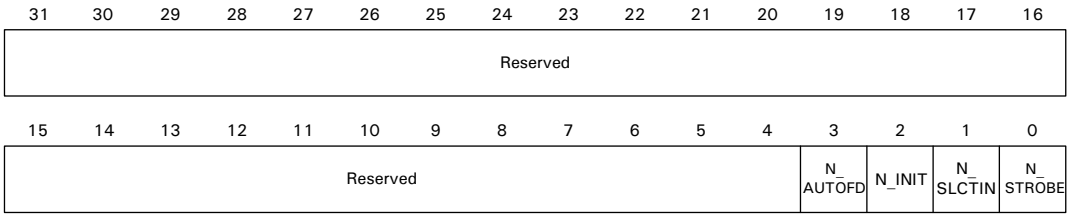
Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:08	N/A	Reserved	N/A	N/A
D07:00	R	pd	N/A	**Printer data pins** Allows the CPU to read the status of the 8-bit data bus directly.

Table 419: pd — Printer Data Pins register

Port Status register, host

Address: 9040 0104



Register bit assignment

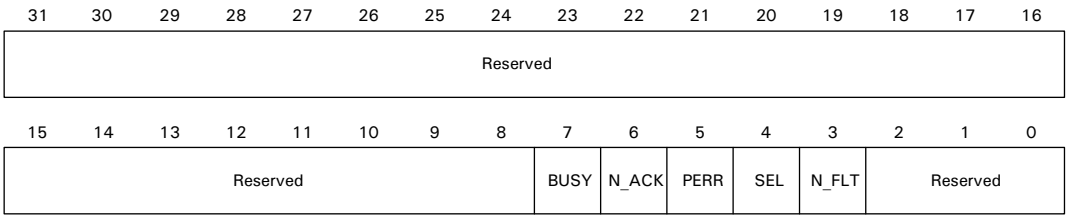
Bits	Access	Mnemonic	Reset	Description
D31:04	N/A	Reserved	N/A	N/A
D03	R	N_AUTOFD	N/A	Allows the CPU to read the status of the host control pins directly. The meaning of each bit varies, depending on whether the mode is compatibility, nibble, byte, or ECP.
D02	R	N_INIT	N/A	
D01	R	N_SLCTIN	N/A	
D00	R	N_STROBE	N/A	

Table 420: psr — Port Status register, host

Port Control register

Address: 9040 0108

Note: The Port Control register can control IEEE 1284 pins *only* if no modes are enabled in the Master Enable register (see"Master Enable register" on page 713).



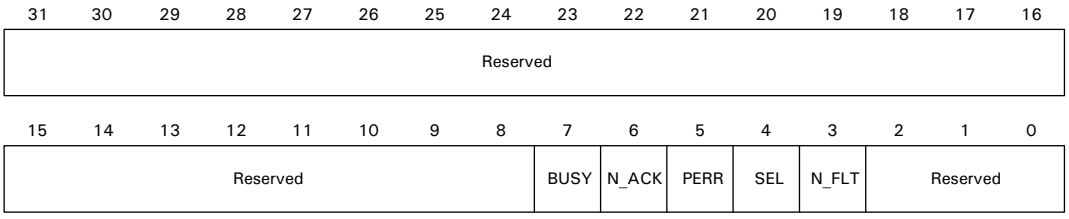
Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:08	N/A	Reserved	N/A	N/A
D07	R/W	BUSY	0x0	Allows the CPU to directly control the IEEE 1284 pin values. The meaning of each bit varies, depending on whether the mode is compatibility, nibble, byte, or ECP. **Notes:** ■ Bits [07:03] should be set to 1 before the printer is enabled (ecr[0] = '1') to avoid driving IEEE 1284 pins during initialization. ■ AutoNegotiate and AutoTransfer must be turned off before software can take control of these control signals (see "Master Enable register" on page 713).
D06	R/W	N_ACK	0x0	
D05	R/W	PERR	0x0	
D04	R/W	SEL	0x0	
D03	R/W	N_FLT	0x0	
D02:00	N/A	Reserved	N/A	N/A

Table 421: pcr — Port Control register

Port Status register, peripheral

Address: 9040 010C



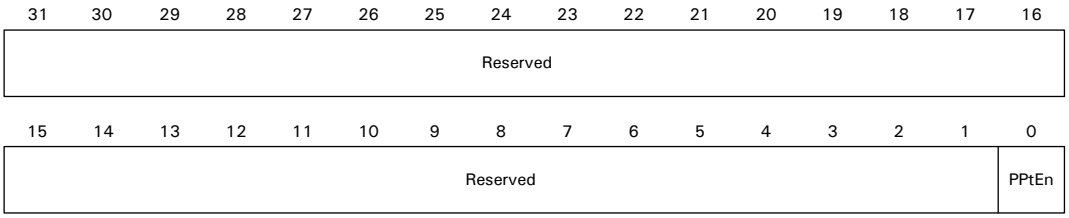
Bits	Access	Mnemonic	Reset	Description
D31:08	R	Reserved	0x0	N/A
D07	R	BUSY	0x0	Allows the CPU to read the status of the peripheral control pins directly. The meaning of each bit varies, depending on whether the mode is compatibility, nibble, byte, or ECP.
D06	R	N_ACK	0x0	
D05	R	PERR	0x0	
D04	R	SEL	0x0	
D03	R	N_FLT	0x0	
D02:00	R	Reserved	0x0	N/A

Table 422: pin — Port Status register, peripheral

Feature Control Register A

Address: 9040 0114

Feature Control Register A enables buffer trigger levels for printer port operations.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:01	N/A	Reserved	N/A	N/A
D00	R/W	PPtEn	0x0	**Printer port enable** 0 Force IEEE 1284 outputs to high impedance 1 Enable normal operation, depending on mode

Table 423: fea — Feature Control Register A

Feature Control Register B

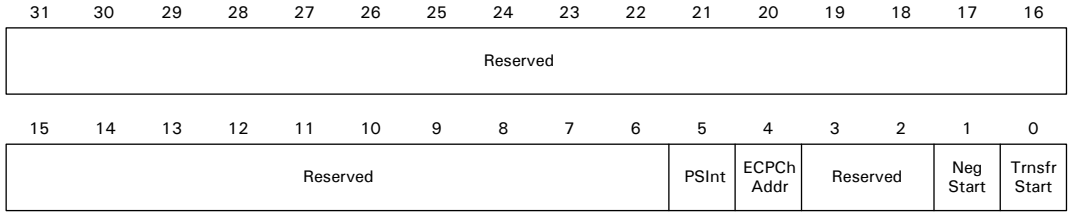
Address: 9040 0118

You must set bit[0] to 1 in Feature Control Register B. Bits[31:01] are reserved.

Interrupt Enable register

Address: 9040 011C

The Interrupt Enable register enables interrupts to be generated on certain conditions.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:06	N/A	Reserved	N/A	N/A

Table 424: fei — Interrupt Enable register

Bits	Access	Mnemonic	Reset	Description
D05	R/W	PinSelectInterrupt	0x0	**Pin select interrupt enable** 0 Disable 1 Enable
D04	R/W	ECPChannel Address	0x0	**Channel address update detect interrupt enable** 0 Disable 1 Enable
D03:02	N/A	Reserved	N/A	N/A
D01	R/W	NegotiationStart	0x0	**Negotiation start interrupt enable** 0 Disable 1 Enable This interrupt is triggered when the rising edge of SELECTIN is found while in compatibility mode.
D00	R/W	TransferStart	0x0	**Transfer start interrupt enable** 0 Disable 1 Enable This interrupt is triggered when the falling edge of STROBE is found while in compatibility mode.

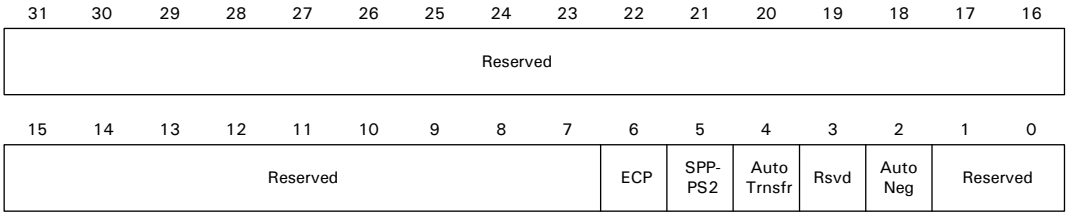
Table 424: fei — Interrupt Enable register

Master Enable register

Address: 9040 0120

The Master Enable register enables different IEEE 1284 modes and automatic transfer modes.

Note: Set both AutoTransfer and AutoNegotiate to enable hardware to control the 1284 peripheral interface signals.



Register bit assignment

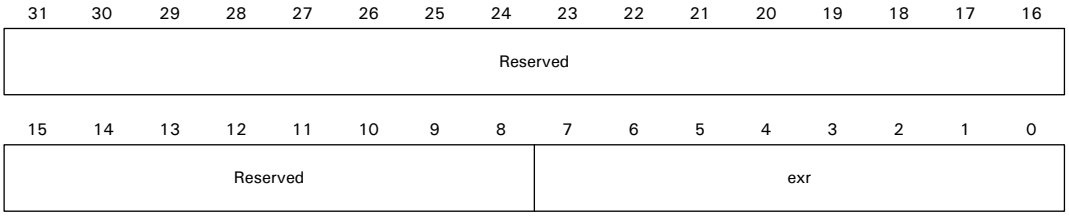
Bits	Access	Mnemonic	Reset	Description
D31:07	N/A	Reserved	N/A	N/A
D06	R/W	ECP	0x0	**ECP mode** 0 Disable 1 Enable
D05	R/W	SPP–PS2	0x0	**SPP–PS2 mode** 0 Disable 1 Enable
D04	R/W	AutoTransfer	0x0	**Auto transfer mode** 0 Disable 1 Enable
D03	N/A	Reserved	N/A	N/A
D02	R/W	AutoNegotiate	0x0	**Auto negotiate mode** 0 Disable 1 Enable
D01:00	N/A	Reserved	N/A	N/A

Table 425: fem — Master enable register

Extensibility Byte Requested by Host

Address: 9040 0124

This register is updated shortly after a new negotiation occurs (event 4 of the negotiation process; see the IEEE 1284 standard for more information).



Register bit assignment

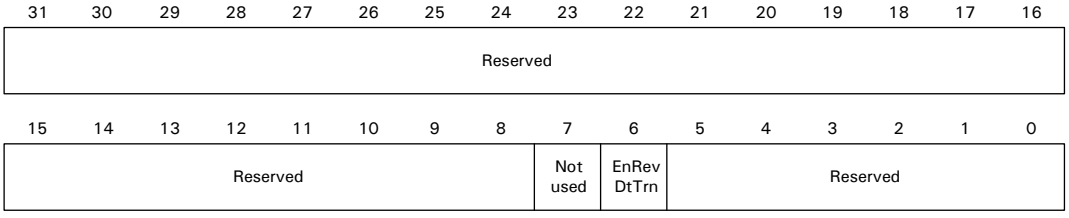
Bits	Access	Mnemonic	Reset	Description
D31:08	N/A	Reserved	N/A	N/A
D07:00	R/W	exr	0x0	**Extensibility byte** Stores the extensibility byte received from the host.

Table 426: exr — Extensibility Byte Requested by Host register

Extended Control register

Address: 9040 0128

The Extended Control register enables additional core features.



Register bit assignment

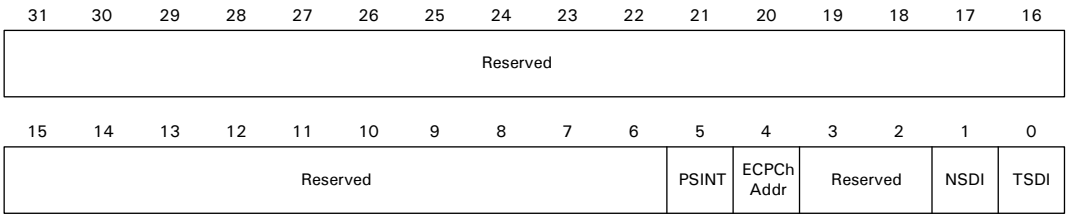
Bits	Access	Mnemonic	Reset	Description
D31:08	N/A	Reserved	N/A	N/A
D07	N/A	Not used	0x0	Set to 1.
D06	R/W	Enable reverse data transfers	0x0	0 Disable 1 Enable
D05:00	N/A	Reserved	N/A	N/A

Table 427: ecr — Extended Control register

Interrupt Status register

Address: 9040 012C

Interrupts are cleared when this register is read. These interrupts are needed by software no matter which mode (DMA or CPU) is being used.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:06	N/A	Reserved	N/A	N/A
D05	R	PSINT	0x0	Pin select interrupt
D04	R	ECP Channel Address	0x0	Channel address update detect interrupt
D03:02	N/A	Reserved	N/A	N/A
D01	R	NSDI	0x0	Negotiation start detect interrupt

Table 428: sti — Interrupt Status register

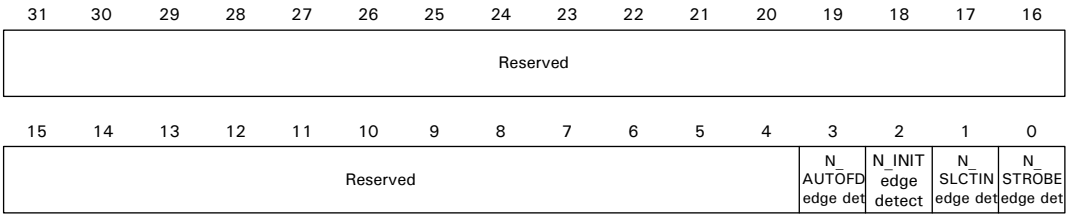
Bits	Access	Mnemonic	Reset	Description
D00	R	TSDI	0x0	Transfer start detect interrupt

Table 428: sti — Interrupt Status register

Pin Interrupt Mask register

Address: 9040 0134

The Pin Interrupt Mask register enables IEEE 1284 pin interrupts.



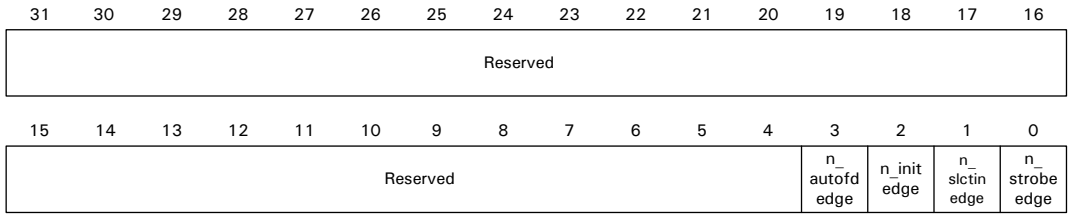
Bits	Access	Mnemonic	Reset	Description
D31:04	N/A	Reserved	0x0	N/A
D03	R/W	n_autofd edge detect	0x0	0 Disable 1 Enable
D02	R/W	n_init edge detect	0x0	
D01	R/W	n_selectin edge detect	0x0	
D00	R/W	n_strobe edge detect	0x0	

Table 429: msk — Pin Interrupt Mask register

Pin Interrupt Control register

Address: 9040 0138

The Pin Interrupt Control register configures IEEE 1284 pin interrupt edge levels.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:04	R	Reserved	0x0	N/A
D03	R/W	n_autofd edge	0x0	0 Falling edge 1 Rising edge
D02	R/W	n_init edge	0x0	
D01	R/W	n_slctin edge	0x0	
D00	R/W	n_strobe edge	0x0	

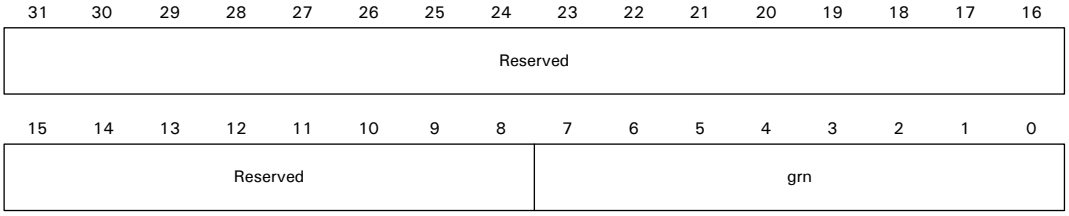
Table 430: pit — Pin Interrupt Control register

Granularity Count register

Address: 9040 0168

The Granularity Count register controls the value of the granularity counter for automatic processing modes.

Note: According to the IEEE 1284 standards spec, the peripheral has a T_p (500ns) minimum setup pulse width for some signals. If, for example, the BBus is set to run at 50 MHz (20ns clock period), the Granularity Count register should be set to 25 (0x19) [500ns / 20ns].



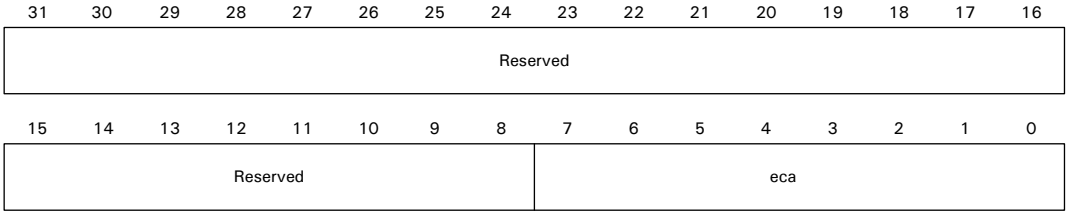
Bits	Access	Mnemonic	Reset	Description
D31:08	R	Reserved	0x0	N/A
D07:00	R/W	grn	0x0	**Granularity counter** Determines the number of BBus clock periods between peripheral signal changes on the IEEE 1284 bus.

Table 431: grn — Granularity Count register

Forward Address register

Address: 9040 0174

The Forward Address register is updated when a channel address command is received during a forward ECP transfer.



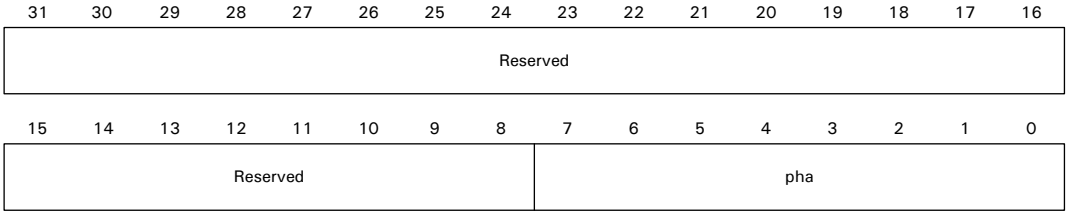
Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:08	R	Reserved	0	N/A
D07:00	R	eca	0	Forward address.

Table 432: eca — Forward Address register

Core Phase (IEEE1284) register

Address: 9040 0178



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:08	R	Reserved	0x0	N/A
D07:00	R	pha	0x0	0x00spp forward idle 0x01 spp forward data transfer 0x0f spp reset 0x14 negotiate phase 0x18 terminate phase 0x24 nibble/byte reverse idle 0x26 nibble/byte reverse data transfer (see **Warning** below**)** 0x28 nibble/byte host busy data not available 0x2C nibble/byte host busy data available 0x2E nibble/byte host interrupt 0x30 ecp forward idle 0x31 ecp forward data transfer 0x34 ecp reverse idle 0x36 ecp reverse data transfer 0x38 ecp host recovery 0x3C ecp reverse to forward phase transition 0x3E ecp forward to reverse phase transition 0x3F ecp setup phase

Table 433: Core Phase register

Warning: The NS9775 cannot proceed to the Host Busy Data Available protocol state directly from negotiation state. If the host software supports the 1284 protocol reverse idle and interrupt host states (events 7, 18 – 20), the impact is a one-time loss of approximately 2,000ns at the beginning of data transfer. If the host does not support these states, however, the NS9775 will be unable to transmit data in nibble or byte mode. Note that there is no impact for a host that fully implements IEEE 1284.

USB Controller Module

CHAPTER 16

USB 2.0 provides a standard “plug-and-play” interface for desktop communications at low to moderate speeds. The USB module in NS9775 supports both full-speed (12Mbps) and low-speed (1.5 Mbps) operation.

Overview

USB consists of point-to-point connections between one host and any number of hubs and devices; the number of hubs and devices combined cannot exceed 127. Point-to-point connections are established between a *downstream* port and an *upstream* port, as shown:

Host/hub/device	Description
Host	■ Has one downstream port ■ If has multiple downstream ports, constitutes multiple *networks*
Hub	■ Has one upstream port and multiple downstream ports ■ Connects to devices or other hubs using downstream ports ■ Connects to hosts or other hubs using upstream ports
Device	■ Has one upstream port ■ Connects to hubs or hosts

USB module architecture

The USB module is comprised of a separate host block and device block (see Figure 104). You can enable the device block or the host block — but never both at the same time.

The device block provides the resources for 12 logical endpoints that can be reconfigured by the device driver. The device block includes a DMA function to preload data for *in* endpoints, stuff data for *out* endpoints into system memory, and stuff data for some packets into system memory.

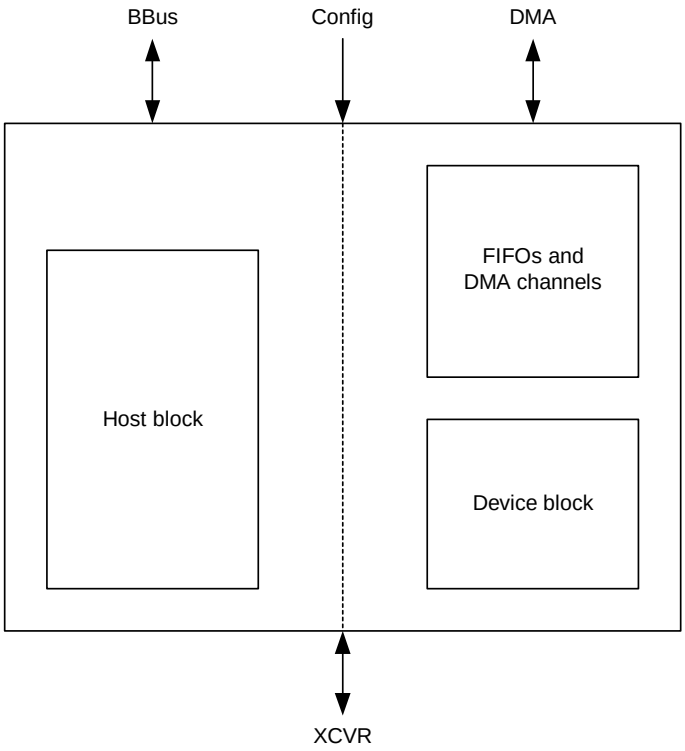


Figure 104: USB module architecture

The device block handles most packets that contain control and/or configuration information requiring device driver interaction to maintain only the DMA descriptor lists. The device block provides the appropriate handshake responses to USB. Control commands that require a response require the device driver to prepare a response based on a unique identifier supplied by the device block. Control commands not handled by the device block require the device driver to inspect the data provided by the setup phase of the packet, construct the required response, and initiate the DMA of the response data to the device block. The initial "try" of such commands typically is greeted with a NAK due to the lack of an available response. Later retries eventually result in the transmission of the response. Packets that contain data or require data transfer are handled by a multi-channel DMA function in the device block. Each pipe is associated with a specific DMA channel. If the DMA channel for a given pipe has not

been configured or updated, or otherwise is not ready to send or receive the required data, the device block issues NAKs to the USB.

The host block supports the Open Host Controller Interface (OHCI) interface model for USB communications. The host block provides the registers and BBus mastering capability to traverse transaction lists in system memory per the OHCI interface, as well as transferring the in/out data to and from system memory.

USB device block

Figure 105 shows the architecture of the USB device block:

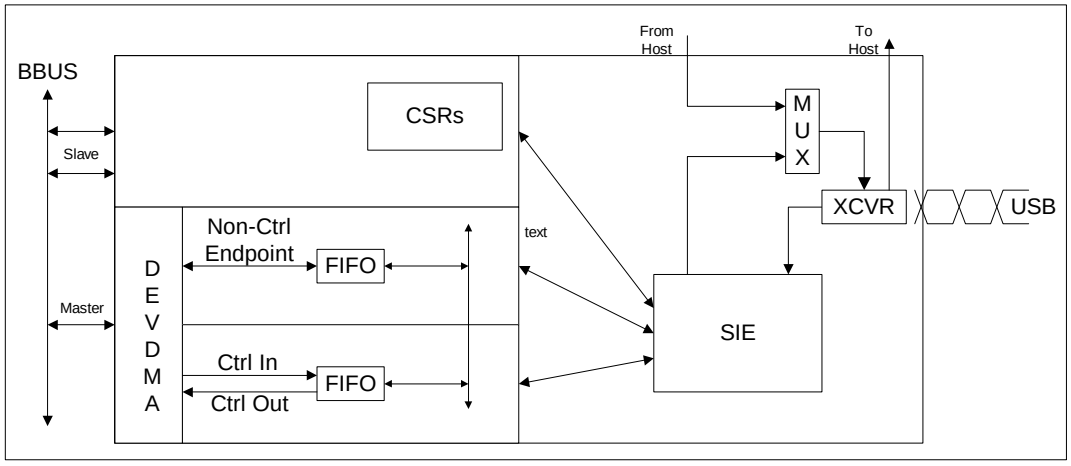


Figure 105: USB device block

Control and status

The control and status for the USB device block is provided through the slave interface. The device block contains the registers used to program each of the 12 logical endpoints and the five configurations.

Packet and data flow

The device block responds to packets initiated by the host. There are 16 DMA channels in this block. DMA channels 1 and 2 move data to and from system memory for control transfers for logical endpoint 0. DMA channels 3 through 13 move data for logical endpoints 1 through 11, respectively. DMA channels 14 through 16 are not used in the USB module.

Data for each logical endpoint travels through a four-word FIFO. Logic included with the FIFOs interface the Master I/F to the DMA channels. The serial interface engine (SIE) performs the tasks required to receive and send packets to and from a USB host.

The device driver writes the endpoint descriptor, configuration identifier register, string identifiers, DMA parameters, and the direction of data transmission for logical endpoints 1–11. From that point, the device driver monitors packet reception/transmission success, and maintains the DMA descriptor lists. DMA Channel 1 DMA descriptors are *incoming*; that is, they move data from USB to memory. DMA channel 2 DMA descriptors are *outgoing*; that is, they move data from memory to the USB. The remainder of the DMA descriptors must follow the direction of data flow for the corresponding logical endpoint, which is also specified in the control/status register for the channel.

When a packet is received, a DMA descriptor must be available to move the required data; otherwise, the packet fails. If a descriptor remains unavailable, the FIFOs will be exhausted and an underrun or overrflow condition occurs. Bits in the corresponding FIFO Status register are set. DMA channels can be used to signal a DMA with no descriptors available.

Control in packets

Control in packets require device driver intervention. An “identifier” is stored in the status field of a retired DMA descriptor doe DMA channel 1. The device driver constructs a response and moves the response from system memory to the USB with DMA channel 2. The USB response to the initial reception of the control in packet is to store the identifier, then NAK the packet; this causes the host to retry the packet. If the outgoing data has been moved to the USB, the data is output upon retry. Once a control in packet has been received, all control in packets are NAK’d, and their identifiers are not stored. The first control in packet received following the successful transmission of data for the previous “pending” packet becomes the new “pending” packet.

Logical and physical endpoints

Each alternate of each interface of each configuration can use as many as 16 logical endpoints. Physical endpoints in the device block are programmable by software for configuration/interface/alternate number. type, direction, and `MaxPacketSize`. A physical endpoint, then, functions as one logical endpoint in one alternate of one interface of one configuration. The number of physical endpoints required is therefore equal to the total number of logical endpoints in each alternate of each interface of each configuration.

The device block is configured to hold 12 physical endpoints, endpoint 0, and 11 non-control endpoints, with a maximum of 5 interfaces. This allows simultaneous operation of the printer class, still image class, and three instances of the data class. Programming of the physical endpoints and the descriptors provided allow you to reassign any of the physical endpoints to any one of the five interfaces. A “multi-function” fax/printer scanner device can take the place of three instances of the data class if no more than six physical endpoints are required.

Slew rates

USB PHY has a greater than specified slew rate in low speed device mode. Faster slew rates may cause compatibility issues with low speed hosts.

Host block

The USB host block contains the resources to implement an OHCI host. These resources include a power control signal for USB port power. Figure 106 shows the architecture for the USB host block.

Control and status

The control and status for the USB host block is provided using the slave interface. The registers support the OHCI specification.

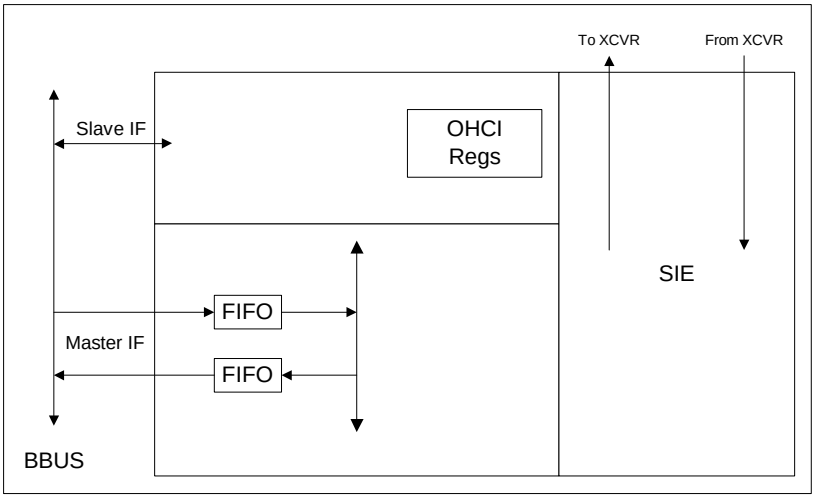


Figure 106: USB host architecture

Packet data flow

The host block initiates all transfers on the USB. Data travels through a four-word FIFO in either direction. The Serial Interface Engine (SIE) performs the tasks required to receive and send packets on the USB.

The host block is the master of the USB. At the highest level, the host maintains a database of the existing network topology, and can reconfigure any associated device.

At the next level, there are four linked lists of endpoint descriptors, each tied to one or more transfer descriptors. The four lists correspond to the four endpoint types that are accessed in a specified priority. The host begins processing these lists each millisecond, after sending the SOF packet. When a given endpoint descriptor is processed, the host generates a packet to move data and the transfer descriptor(s) defines the source or destination of the data in system memory. Interrupts generally are generated as each transfer descriptor is retired.

The core is connected with a master interface on the BBus to move incoming or outgoing data to system memory. Based on expected timing of four microseconds for bus turnaround, the four-word FIFOs included in the core prevent underrun and/or overrun occurrences. Bursting is supported to minimize the bus bandwidth that is

consumed. Burst transfers move a maximum of 8 bytes in long word transactions. FIFO content from more than one transfer descriptor is broken into separate memory operations.

USB device endpoint

Any USB device requires a bidirectional control endpoint located at endpoint #0. The data FIFOs in the USB device application logic are unidirectional, so two data FIFOs are used to create a single bidirectional endpoint. FIFO #1 handles the USB-OUT packets and FIFO #2 handles the USB-IN packets. Table 434 describes the fields in the FIFO Status and Control registers that *must be set* in order for the bidirectional control endpoint to operate. The remaining Control register fields are application-specific.

FIFO	Mnemonic	Value	Description
1	TYPE	00	Control endpoint
1	DIR	0	USB-OUT direction
2	TYPE	00	Control endpoint
2	DIR	1	USB-IN direction

Table 434: Control endpoint register requirements

Transmission error handling

USB protocol supports the error-free transmission of packets for bulk and interrupt endpoints. The USB device application logic contains some control structures to help the software with this task. Transmission errors are defined as bit-stuffing errors or CRC check errors.

Handling USB-IN packet errors

USB-IN packet errors are sent from the USB device to the USB host. The USB host either responds with an ACK packet to indicate successful transmission or does not respond at all to indicate that there was an error in transmission.

These are the steps that must be taken to retransmit the packet in error:

1. Determine that the error has occurred through an interrupt. The hardware places the endpoint FIFO into reset state and flushes the contents.
2. Determine which endpoint is involved, using the FIFO Status registers.
3. Read the valid packets-transmitted-count from the Packet Control register and use it to compute a new buffer descriptor source address and buffer length. Update the current buffer descriptor in system memory. The current DMA buffer descriptor can be determined by reading the index field in the DMA Control register (see "DMA Control register" on page 526).
4. Write a 1 to the BDR (buffer descriptor refetch) and CE (channel enable) fields in the DMA Control register to force a refetch of the buffer descriptor when the channel next wins arbitration.
5. Take the USB device endpoint FIFO out of reset. At this point, the DMA controller will refetch the buffer descriptor as well as the packet in error and all remaining data in the DMA buffer.

Handling USB-OUT packet errors

USB-OUT packets are sent from the USB host to the USB device. The USB device either responds with an ACK packet to indicate successful transmission or does not respond at all to indicate that there was an error in transmission. If there was an error, the current DMA buffer is closed and the DMA buffer descriptor status field indicates that an error has occurred. Through this status information, software knows to discard the last packet in the buffer, as the USB host will retransmit the packet in error. The DMA controller fetches the next buffer descriptor, and the retransmitted packet will be the first packet in the new DMA data buffer.

USB block registers

The USB module configuration registers are located at base address 9010_0000. Table 435 provides the address register map for the USB “modules” within the USB block.

Address range	Register space (module)
0x90100000–0x90100FFF	USB Global Control and Status
0x90101000–0x90101FFF	USB Host Block
0x90102000–0x90102FFF	USB Device Block
0x90103000–0x90103FFF	USB Device Endpoint FIFOs
0x90110000–0x9011FFFF	USB Device DMA (see the BBus DMA Controller chapter for details about these registers)

Table 435: USB register address map

USB Global registers

Table 436 provides the addresses for the USB Global registers.

All configuration registers must be accessed as 32-bit words and as single accesses only. No bursting is allowed.

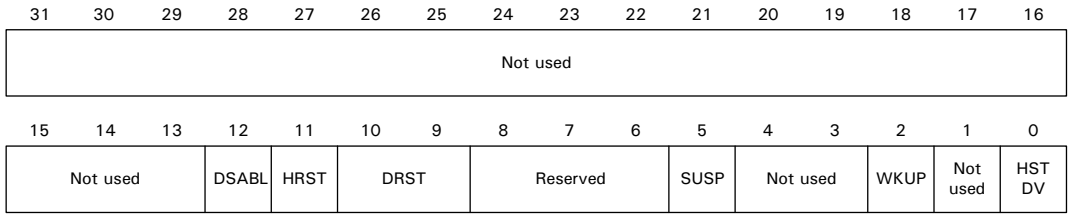
Address	Register
9010 0000	Global Control/Status register
9010 0004	Device Control/Status register
9010 000C	Global Interrupt Enable
9010 0010	Global Interrupt Status
9010 0014	Device IP Programming Control/Status

Table 436: USB Global registers address map

Global Control and Status register

Address: 9010 0000

The Global Control and Status register contains all USB global and status information. The USB can operate as a device or host, but cannot operate as both simultaneously unless used in *feedback mode*. Feedback mode is useful for development and testing only. The inactive block (host or device) is held in reset.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:13	N/A	Not used	0x00000	Always read as 0.
D12	R	DISABLE (DSABL)	0	**Disable** 0 Indicates that USB is enabled 1 Indicates that USB is disable Indicates whether USB is disabled or enabled.
D11	R	HRST	1	**Host reset** 0 Indicates that the host block is enabled 1 Indicates that the host block is in reset Provides the host block reset status.
D10:09	R	DRST	11	**Device reset** 00 Indicates that the device block is enabled 01 Indicates that the device block is in reset Provides the device block reset status.
D08:06	N/A	Reserved	N/A	N/A

Table 437: Global Control and Status register

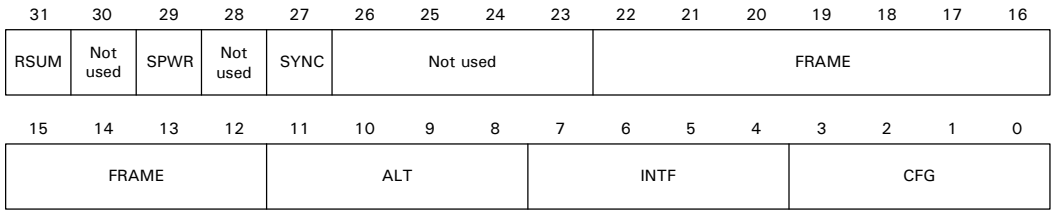
Bits	Access	Mnemonic	Reset	Description
D05	R	SUSP	0	**Suspend** 0 The USB device is not in a suspended state 1 The USB device is in a suspended state Indicates whether the USB device is in a suspended state.
D04:03	N/A	Not used	0	Always write a 0.
D02	R/W	WKUP	0	**Wakeup** Value depends on the value written to the HST_DEV field (bit 0 in this register). ■ When the NS9775 is in device mode, the device driver can write a 1 to this field to enable remote wakeup. ■ When the NS9775 is in host mode, this field is ignored.
D01	R	Not used	1	Always read as 1.
D00	R/W	HSTDV	1	**Host/device (HST_DEV)** 0 USB host mode 1 USB device mode Indicates the mode of the USB controller.

Table 437: Global Control and Status register

Device Control and Status register

Address: 9010 0004

The Device Control and Status register contains the USB device-block-specific control and status information.



Register bit assignment

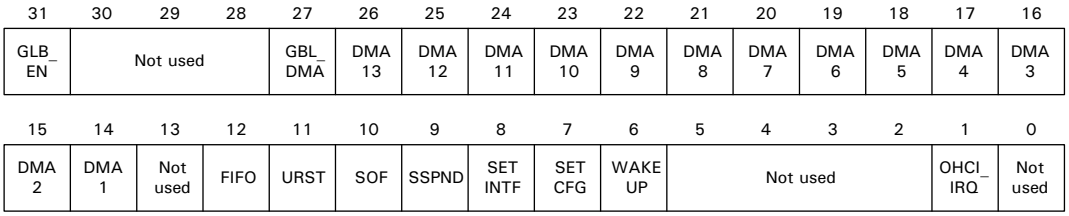
Bits	Access	Mnemonic	Reset	Description
D31	R/W	RESUME (RSME)	0	**Resume** Set to 1 by the device driver to initiate a resume sequence. This field is cleared to a 0 to end a resume sequence.
D30	N/A	Not used	0	Always read as 0.
D29	R/W	SPWR	0	**Self-powered (SELF_PWR)** This field should always be written as 1, since the NS9775 is always self-powered.
D28	N/A	Not used	0	Always write to 1.
D27	R/W	SYNC	0	**SYNC_FRAME support** Indicates whether the device block supports the SYNC_FRAME packet. 0 SYNC_FRAME packet is not supported 1 SYNC_FRAME packet is supported When set to 0, the device replies to a SET_DESCRIPTOR packet with a STALL handshake.
D26:23	N/A	Not used	0	Always read as 0.
D22:12	R	FRAME	0x000	**Frame number** Contains the current frame number. **Note:** This field is used for diagnostic purposes only.
D11:08	R	ALT	0x0	**Alternate value** Contains the current alternate value for the device block from a SET INTERFACE packet.
D07:04	R	INTF	0x0	**Interface value** Contains the current interface value for the device block from a SET INTERFACE packet.
D03:00	R	CFG	0x0	**Configuration value** Contains the current configuration value for the device block from a SET CONFIGURATION packet.

Table 438: Device Control and Status register

Global Interrupt Enable register

Address: 9010 000C

The Global Interrupt Enable register contains the global interrupt enable information. *All interrupts are enabled by writing a 1 and disabled by writing a 0*.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31	R/W	GBL_EN	0	**Global interrupt enable** Enables all interrupts. For normal operation, this field should be written to 1.
D30:28	R/W	Not used	0	Always write to 0.
D27	R/W	GBL_DMA	0	**Global DMA interrupt enable** Enables all DMA-generated interrupts. For normal operation, this field should be written to 1.
D26	R/W	DMA13	0	DMA channel 13 interrupt
D25	R/W	DMA12	0	DMA channel 12 interrupt
D24	R/W	DMA11	0	DMA channel 11 interrupt
D23	R/W	DMA10	0	DMA channel 10 interrupt
D22	R/W	DMA9	0	DMA channel 9 interrupt
D21	R/W	DMA8	0	DMA channel 8 interrupt
D20	R/W	DMA7	0	DMA channel 7 interrupt
D19	R/W	DMA6	0	DMA channel 6 interrupt

Table 439: Global Interrupt Enable register

Bits	Access	Mnemonic	Reset	Description
D18	R/W	DMA5	0	DMA channel 5 interrupt
D17	R/W	DMA4	0	DMA channel 4 interrupt
D16	R/W	DMA3	0	DMA channel 3 interrupt
D15	R/W	DMA2	0	DMA channel 2 interrupt
D14	R/W	DMA1	0	DMA channel 1 interrupt
D13	R/W	Not used	0	Always write to 0.
D12	R/W	FIFO	0	Generate an interrupt when any FIFO interrupt Status field is set and the corresponding interrupt is enabled using the FIFO Interrupt Enable register.
D11	R/W	URST	0	Generate an interrupt when the NS9775 is in device mode and receives an interrupt from the host.
D10	R/W	SOF	0	Generate an interrupt when the NS9775 is in device mode and receives an SOF (start of frame) packet.
D09	R/W	SUSPEND (SSPND)	0	Generate an interrupt when the SUSPEND (SUSP) field in the Global Interrupt Status register (see page 739) is asserted.
D08	R/W	SETINTF	0	Generate an interrupt when the SETINTF field in the Global Interrupt Status register (see page 739) is asserted.
D07	R/W	SETCFG	0	Generate an interrupt when the SETCFG in the Global Interrupt Status register (see page 739) is asserted.
D06	R/W	WAKEUP	0	Generate an interrupt when the WAKEUP field in the Global Interrupt Status register (see page 740) is asserted.
D05:02	N/A	Not used	0	Always write to 0.
D01	R/W	OHCI_IRQ	0	Generate an interrupt when the OHCI_IRQ field in the Global Interrupt Status register (see page 740) is asserted.
D00	N/A	Not used	N/A	Always write to 0.

Table 439: Global Interrupt Enable register

Global Interrupt Status register

Address: 9010 0010

The Global Interrupt Status register contains the global interrupt status information. *All status bits are active high (1) and all interrupts that are serviced here are cleared by writing a 1 to the appropriate field***.**

For diagnostics, each bit serviced here can also be set to 1 by writing a 1 when the bit is set to 0.

Note: The DMA interrupts must be serviced in the USB DMA device block. The FIFO interrupts must be serviced in the FIFO Interrupt Status register.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Not used	Rsvd	Not used		GBL_DMA	DMA 13	DMA 12	DMA 11	DMA 10	DMA 9	DMA 8	DMA 7	DMA 6	DMA 5	DMA 4	DMA 3

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DMA 2	DMA 1	Rsvd	FIFO	URST	SOF	SSPND	SET INTF	SET CFG	WAKE UP	Reserved				OHCI_IRQ	Rsvd

Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31	N/A	Not used	0	Always read as 0.
D30	N/A	Reserved	N/A	N/A
D29:28	N/A	Not used	0	Always read as 00.
D27	R	GBL_DMA	0	Bit-wise logical OR of the DMA# fields.
D26	R	DMA13	0	DMA channel 13 interrupt. Service in the USB DMA block.
D25	R	DMA12	0	DMA channel 12 interrupt. Service in the USB DMA block.
D24	R	DMA11	0	DMA channel 11 interrupt. Service in the USB DMA block.
D23	R	DMA10	0	DMA channel 10 interrupt. Service in the USB DMA block.

Table 440: Global Interrupt Status register

Bits	Access	Mnemonic	Reset	Description
D22	R	DMA9	0	DMA channel 9 interrupt. Service in the USB DMA block.
D21	R	DMA8	0	DMA channel 8 interrupt. Service in the USB DMA block.
D20	R	DMA7	0	DMA channel 7 interrupt. Service in the USB DMA block.
D19	R	DMA6	0	DMA channel 6 interrupt. Service in the USB DMA block.
D18	R	DMA5	0	DMA channel 5 interrupt. Service in the USB DMA block.
D17	R	DMA4	0	DMA channel 4 interrupt. Service in the USB DMA block.
D16	R	DMA3	0	DMA channel 3 interrupt. Service in the USB DMA block.
D15	R	DMA2	0	DMA channel 2 interrupt. Service in the USB DMA block.
D14	R	DMA1	0	DMA channel 1 interrupt. Service in the USB DMA block.
D13	N/A	Reserved	N/A	N/A
D12	R	FIFO	0	Bit-wise logical OR of the FIFO interrupt status fields.
D11	RW1TC	URST	0	Asserted when the NS9775 is in device mode and receives an interrupt from the host.
D10	RW1TC	SOF	0	Asserted when the NS9775 is in device mode and receives an SOF (start of frame) packet.
D09	RW1TC	SUSPEND SSPND	0	**Suspend** Asserted when either the device or the host has entered the suspend state.
D08	RW1TC	SETINTF	0	**Set interface** Asserted when the USB is configured for device operation and a set interface packet is received.

Table 440: Global Interrupt Status register

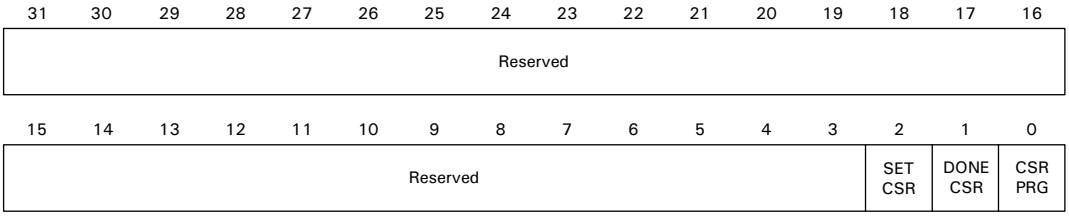
Bits	Access	Mnemonic	Reset	Description
D07	RW1TC	SETCFG	0	**Set configuration** Asserted when the USB is configured for device operation and a set configuration packet is received.
D06	RW1TC	WAKEUP	0	**Wakeup** Asserted when the USB is configured for host operation and the NS9775 moves from the suspend state to the resume state.
D05:02	N/A	Reserved	N/A	**N/A**
D01	RW1TC	OHCI_IRQ	0	**OHCI_IRQ** Asserted when the USB is configured for host operation and the OHCI asserts an interrupt.
D00	N/A	Reserved	N/A	N/A

Table 440: Global Interrupt Status register

Device IP Programming Control/Status register

Address: 9010 0014

The Device IP Programming Control/Status register contains the USB device CSR dynamic programming control and status information. The register allows you to reconfigure the USB device when a SET_CFG or SET_INTF packet is received from the USB host.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:03	R	Not used	0x00000000	This field is always read back as 0x00000000.
D02	R	SETCSR	0	**CSR programming start** Indicates when software can safely start programming the registers. Must be set to 1 before programming can begin.
D01	R/W	DONECSR	0	**CSR programming done** Indicates to the device IP that software has finished programming the CSRs. A value of 1 indicates that software is finished.
D00	R/W	CSRPRG	0	**CSR dynamic programming support** Enables dynamic programming support in the USB device IP. Program this field on powerup, then leave it unchanged. Write a 1 to enable this feature.

Table 441: Device IP Programming Control/Status register

USB host block registers

The USB Host Block registers are for the host controller defined in the Open HCI specification for USB. All references to *HC* refer to the USB host block in the NS9775.

Reserved bits

The Host Controller Driver (HCD) should always preserve the value(s) of the reserved field. When a R/W register is modified, the HCD should first read the register, modify the appropriate bits, then write the register with the reserved bits still containing the read value. As an alternative, the HCD can maintain an in-memory copy of previously written values that can be modified and then written to the Host

Controller (HC) register. When a write to set/clear a register is written, bits written to reserved fields should be 0.

USB host block register address map

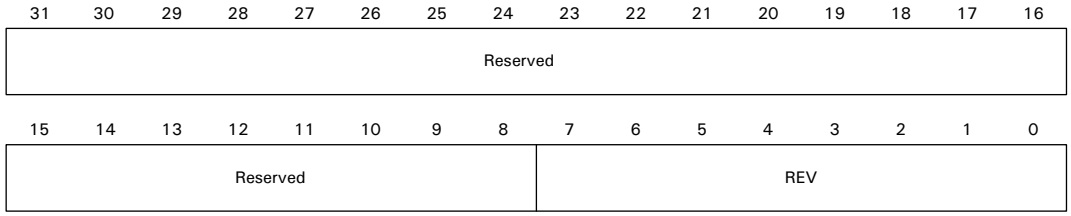
Table 442 provides the addresses of the USB host block registers.

Address	Register
9010 1000	HcRevision register
9010 1004	HcControl register
9010 1008	HcCommandStatus register
9010 100C	HcInterrupt Status register
9010 1010	HcInterruptEnable register
9010 1014	HcInterruptDisable register
9010 1018	HcHCCA (Host Controller Communications Area) register
9010 101C	HcPeriodCurrentED (Endpoint Descriptor) register
9010 1020	HcControlHeadED register
9010 1024	HcControlCurrentED register
9010 1028	HcBulkHeadED register
9010 102C	HcBulkCurrentED register
9010 1030	HcDoneHead register
9010 1034	HcFmInterval (Fm = Frame)
9010 1038	HcFmRemaining register
9010 103C	HcFmNumber register
9010 1040	HcPeriodicStart register
9010 1044	HcLSThreshold register
9010 1048	HcRhDescriptorA register (Rh = Root hub)
9010 104C	HcRhDescriptorB register
9010 1050	HcRhStatus register
9010 1054	HcRhPortStatus[1] register

Table 442: USB Host Block registers address map

HCRevision register

Address: 9010 1000



Register bit assignment

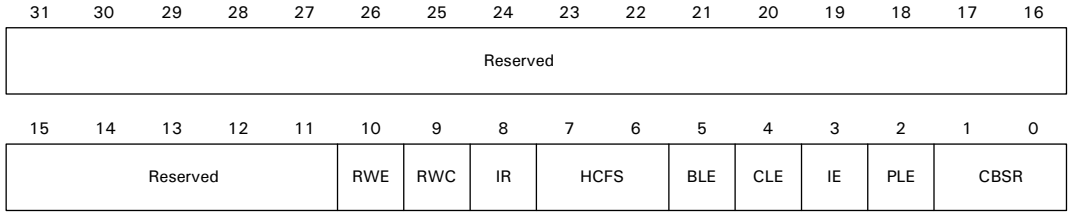
Bits	Access	Mnemonic	Reset	Description
D31:08	N/A	Reserved	N/A	N/A
D07:00	R	REV	10h	Version of the OHCI specification being used.

Table 443: HcRevision register

HcControl register

Address: 9010 1004

The HcControl register defines the operating modes for the host controller. Most of the fields in this register are modified only by the host controller driver, with the exception of the HostControllerFunctionalState and RemoteWakeupConnected fields.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:11	N/A	Reserved	N/A	N/A
D10	R/W	RWE	0b	**RemoteWakeupEnable** Enables or disables the remote wakeup feature when upstream resume signaling is found. When this bit is set and the ResumeDetected bit in the HcInterruptStatus register is set, a remote wakeup is signaled to the host system. Setting this bit has no impact on the generation of hardware interrupts.
D09	R/W	RWC	0b	**RemoteWakeupConnected** Indicates whether the host controller supports remote wakeup signaling. If remote wakeup is supported and used by the system, it is the system firmware's responsibility to set this bit during POST. The host controller clears the bit on a hardware reset, but does not alter the bit on a software reset.
D08	R/W	IR	0b	**InterruptRouting** Determines the routing of interrupts generated by events registered in the HcInterruptStatus register. ■ If clear, all interrupts are routed to the normal host bus interrupt mechanism. ■ If set, interrupts are routed to the system management interrupt. The host controller driver clears this bit on a hardware reset, but does not alter the bit on a software reset. The host controller driver uses this bit as a tag to indicate the ownership of the host controller.

Table 444: HcControl register

Bits	Access	Mnemonic	Reset	Description
D07:06	R/W	HCFS	00b	**HostControllerFunctionalState** (b = binary) 00b USBRESET (initial state) 01b USBRESUME 10b USBOPERATIONAL 11b USBSUSPEND A transition to USBOPERATIONAL from another state causes SOF generation to begin 1 ms later. The host controller driver can determine whether the host controller has begun sending SOFs by reading the StartofFrame field of the HcInterruptStatus register. The host controller can change this field only when in the USBSUSPEND state. The host controller can move from the USBSUSPEND state to the USBRESUME state after detecting the resume signal from a downstream port. The host controller enters the USBSUSPEND state after a software reset, whereas it enters USBRESET after a hardware reset. A hardware reset also resets the root hub, and asserts subsequent reset signaling to downstream ports.
D05	R/W	BLE	0b	**BulkListEnable** Set to enable processing of the bulk list in the next frame. If cleared by the host controller driver, the bulk list is not processed after the next SOF. The host controller checks this bit whenever it determines to process this list. When disabled, the host controller driver can modify the list. If HcBulkCurrentED is pointing to an ED to be removed, the host controller driver must advance the pointer by updating HcBulkCurrentED before re-enabling processing of the list.

Table 444: HcControl register

Bits	Access	Mnemonic	Reset	Description
D04	R/W	CLE	0b	**ControlListEnable** Set to enable processing the control list in the next frame. If cleared by the host controller driver, the control list is not processed after the next SOF. The host controller must check this bit whenever it wants to process the list. When disabled, the host controller driver can modify the list. If HcControlCurrentED is pointing to an ED to be removed, the host controller driver must advance the pointer by updating HcControlCurrentED before re-enabling processing of the list.
D03	R/W	IE	0b	**IsochronousEnable** Enables/disables processing of the isochronous EDs. While processing the periodic list in a frame, the host controller checks the status of this bit when it finds an isochronous ED (F = 1). ■ If set (enabled), the host controller continues processing the EDs. ■ If cleared (disabled), the host controller stops processing of the periodic list (which now contains only isochronous EDs) and begins processing the bulk/control lists. ■ Setting this bit is guaranteed to take effect in the next frame — not the current frame.
D02	R/W	PLE	0b	**PeriodicListEnable** Set to enable the processing of the periodic list in the next frame. If cleared by the host controller driver, the periodic list is not processed after the next SOF. The host controller must check this bit before it starts processing the list.

Table 444: HcControl register

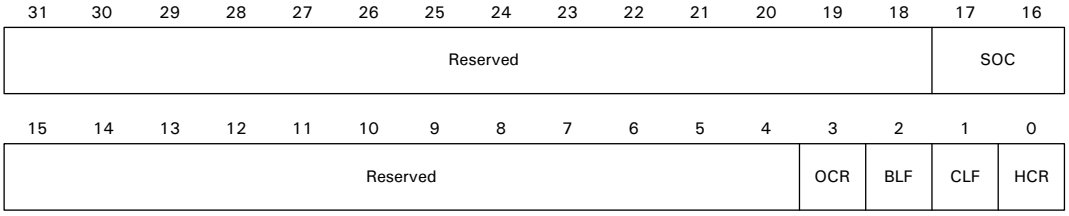
Bits	Access	Mnemonic	Reset	Description
D01:00	R/W	CBSR	00b	**ControlBulkServiceRatio** Specifies the service ratio between control and bulk endpoint descriptors (EDs). Before processing any of the nonperiodic lists, the host controller must compare the ratio specified with its internal count on how many nonempty control EDs have been processed, to determine whether to continue serving another control ED or switch to a bulk ED. The internal count is retained when crossing the frame boundary. In the case of a reset, the host controller driver is responsible for restoring this value. **CBSR** — **# of control EDs over bulk EDs served** 0 — 1 : 1 1 — 2 : 1 2 — 3 : 1 3 — 4 : 1

Table 444: HcControl register

HcCommandStatus register

Address: 9010 1008

The host controller uses the HcCommandStatus register to receive commands issued by the host controller driver, as well as to reflect the current status of the host controller. The HcCommandStatus register appears to the host controller driver as a *write to set* register. The host controller must ensure that bits written as 1 become set in the register while bits written as 0 remain unchanged in the register. The host controller driver can issue multiple distinct commands to the host controller without concern for corrupting previously-issued commands. The host controller driver has normal read access to all bits. The host controller driver has normal read access to all bits.



Register bit description

Bits	Access	Mnemonic	Reset	Description
D31:18	N/A	Reserved	N/A	N/A
D17:16	R	SOC	00b	**SchedulingOverrunCount** Indicates the number of frames with which the host controller has found a scheduling overrun error. A scheduling overrun error occurs when the periodic list does not complete before EOF. When a scheduling overrun error is found, the host controller increments the counter and sets the Scheduling Overrun field in the HcInterruptStatus register (see "HcInterruptStatus register," beginning on page 750). This field initializes to 00b and wraps around at 11b. This field is incremented on each scheduling overrun error, even if the SchedulingOverrun field in the HcInterruptStatus register has already been set. The host controller driver uses this field to monitor any persistent scheduling problems.
D15:04	N/A	Reserved	N/A	N/A
D03	R/W	OCR	0b	**OwnershipChangeRequest** Set by an OS host controller to request a change of control for the host controller. When set, the host controller sets the OwnershipChange field in the HcInterruptStatus register (see "HcInterruptStatus register," beginning on page 750). After the change is made, the OCR bit is cleared and remains so until the next request from OS host controller.

Table 445: HcCommandStatus register

Bits	Access	Mnemonic	Reset	Description
D02	R/W	BLF	0b	**BulkListFilled** Indicates whether there are any TDs on the bulk list. This bit is set by the host controller driver whenever it adds a TD to an ED in the bulk list. When the host controller begins to process the head of the bulk list, it checks the BLF field. As long as the BLF field is 0, the host controller will not start processing the bulk list. If BLF is 1, the host controller starts processing the bulk list and sets the BLF field to 0. If the host controller finds a TD on the list, it sets BLF to 1, which causes bulk list processing to continue. If no TD is found on the bulk list, and if the host controller driver does not set the BLF field, the BLF value will still be 0 when the host controller completes processing the bulk list; the bulk list processing then stops.
D01	R/W	CLF	0b	**ControlListFilled** Indicates whether there are any TDs (task descriptors) on the control list. This bit is set by the host controller driver whenever it adds a TD to an ED in the control list. When the host controller begins to process the head of the control list, it checks the CLF field. As long as CLF is 0, the host controller will not start processing the control list. If CLF is set to 1, the host controller starts processing the control list and sets the CLF field to 0. If the host controller finds a TD on the list, it sets CLF to 1, which causes control list processing to continue. If no TD is found on the control list, and if the host controller does not set the CLF field, the CLF value will still be 0 when the host controller completes processing the control list; control list processing then stops.

Table 445: HcCommandStatus register

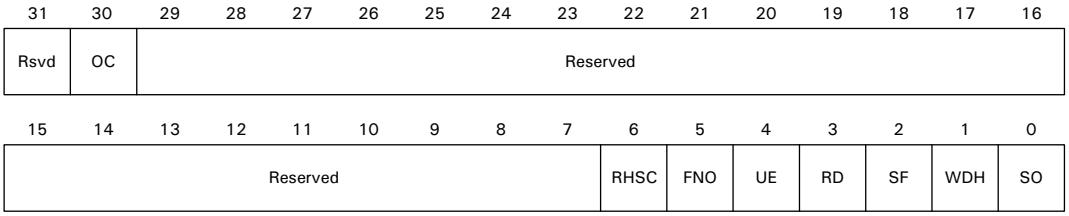
Bits	Access	Mnemonic	Reset	Description
D00	R/W	HCR	0b	**HostControllerReset** Set by the host controller driver to initiate a software reset of the host controller. Regardless of the functional state of the host controller, it moves to USBSUSPEND state. This bit is cleared by the host controller on completion of the reset operation.

Table 445: HcCommandStatus register

HcInterruptStatus register

Address: 9010 100C

The HcInterruptStatus register provides status on various events that cause hardware interrupts. When an event occurs, the NS9775 sets the corresponding bit in this register. When a bit is set, a hardware interrupt is generated if the interrupt is enabled in the HcInterruptEnable register (see "HcInterruptEnable register," beginning on page 752) and the MasterInterruptEnable bit (in the HcInterruptEnable register) is set. The host controller driver can clear specific bits in this register by writing a 1 to the bit positions to be cleared, but cannot set any of these bits.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31	N/A	Reserved	N/A	N/A
D30	R/W	OC	0b	**OwnershipChange** Set by the host controller when the host controller driver sets the OwnershipChangeRequest field in the HcCommandStatus register (see "HcCommandStatus register," beginning on page 747). This event, when unmasked, always generates a system management interrupt (SMI) immediately. This bit is tied to 0b when the SMI pin is not implemented.
D29:07	N/A	Reserved	N/A	N/A
D06	R/W	RHSC	0b	**RootHubStatusChange** Set when the content of the HcRhStatus register (see "HcRhStatus register," beginning on page 773) or any HcRhPortStatus[NumberofDownstreamPort] register (see "HcRhPortStatus[1] register," beginning on page 776) has changed.
D05	R/W	FNO	0b	**FrameNumberOverflow** Set when the most significant bit (MSB), bit 15, of the HcFmNumber (see "HcFmNumber register," beginning on page 766) changes value, from 0 to 1 or 1 to 0, and after HccaFrameNumber has been updated.
D04	R/W	UE	0b	**UnrecoverableError** Set when the host controller finds a system error not related to USB. The host controller should not proceed with any processing nor signaling before the system error has been corrected. The host controller driver clears this bit after the host controller has been reset.

Table 446: HcInterruptStatus register

Bits	Access	Mnemonic	Reset	Description
D03	R/W	RD	0b	**ResumeDetected** Set when the host controller finds that a device on the USB is asserting resume signaling. The transition from no resume signaling to resume signaling causes this bit to be set. This bit is not set when the host controller driver sets the USBRESUME state.
D02	R/W	SF	0b	**StartofFrame** Set by the host controller at each start of a frame and after the update of HccaFrameNumber. The host controller generates a SOF token at the same time.
D01	R/W	WDH	0b	**WritebackDoneHead** Set immediately after the host controller has written HcDoneHead (see "HcDoneHead register," beginning on page 763) to HccaDoneHead. The host controller driver should clear this bit only after it has saved the content of HccaDoneHead.
D00	R/W	SO	0b	**SchedulingOverrun** Set when the USB schedule for the current frame overruns and after the update of HccaFrameNumber. A scheduling overrun also causes the SchedulingOverrunCount in the HcCommandStatus register (see "HcCommandStatus register," beginning on page 747) to be incremented.

Table 446: HcInterruptStatus register

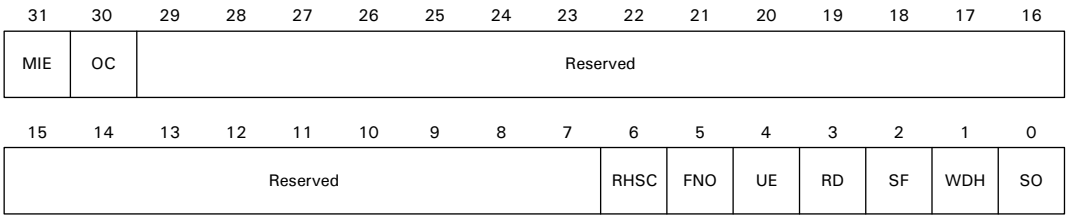
HcInterruptEnable register

Address: 9010 1010

Each enable bit in the HcInterruptEnable register corresponds to an associated interrupt bit in the HcInterrupt Status register (see "HcInterruptStatus register," beginning on page 750). The HcInterruptEnable register controls which events generate a hardware interrupt. When a bit is set in the HcInterruptStatus register **and** the corresponding bit in the HcInterruptEnable register is set **and** the

MasterInterruptEnable bit (D31) in this register), a hardware interrupt is requested on the host bus.

Writing a 1 to a bit in this register sets the corresponding bit; setting a bit to 0 leaves the corresponding bit unchanged. On a read, the current value of this register is returned.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31	R/W	MIE	0b	**Master interrupt enable** 0 Ignored by the host controller 1 Enables interrupt generation due to events specified in the other bits of this register.
D30	R/W	OC	0b	**Ownership change** 0 Ignore 1 Enable interrupt generation due to ownership change.
D29:07	N/A	Reserved	N/A	N/A
D06	R/W	RHSC	0b	**Root hub status change** 0 Ignore 1 Enable interrupt generation due to root hub status change.
D05	R/W	FNO	0b	**Frame number overflow** 0 Ignore 1 Enable interrupt generation due to frame number overflow.

Table 447: HcInterruptEnable register

Bits	Access	Mnemonic	Reset	Description
D04	R/W	UE	0b	**Unrecoverable error** 0 Ignore 1 Enable interrupt generation due to unrecoverable error.
D03	R/W	RD	0b	**Resume detect** 0 Ignore 1 Enable interrupt generation due to resume detect.
D02	R/W	SF	0b	**Start of frame** 0 Ignore 1 Enable interrupt generation due to start of frame.
D01	R/W	WDH	0b	**HcDoneHead writeback** 0 Ignore 1 Enable interrupt generation due to HcDoneHead writeback.
D00	R/W	SO	0b	**Scheduling overrun** 0 Ignore 1 Enable interrupt generation due to scheduling overrun.

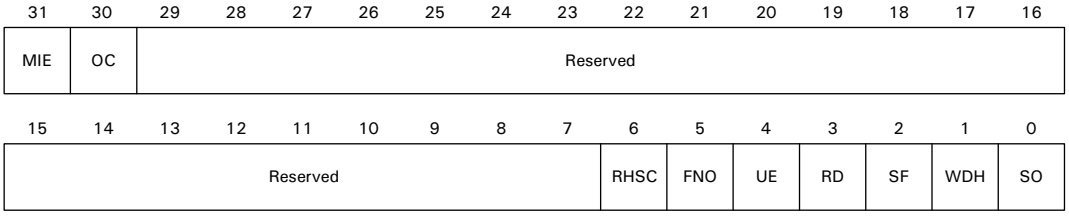
Table 447: HcInterruptEnable register

HcInterruptDisable register

Address: 9010 1014

Each disable bit in the HcInterruptDisable register corresponds to an associated interrupt bit in the HcInterruptStatus register (see "HcInterruptStatus register," beginning on page 750). The HcInterruptDisable register works in conjunction with the HcInterruptEnable register (see "HcInterruptEnable register," beginning on page 752). Writing a 1 in the HcInterruptDisable register clears the corresponding bit in the HcInterruptEnable register; writing a 0 to a bit in the HcInterruptDisable register leaves the corresponding bit in the HcInterruptEnable register unchanged.

On a read, the current value of the HcInterruptEnable register is returned.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31	R/W	MIE	0b	**Master interrupt enable** 0 Ignored by the host controller. 1 Disables interrupt generation due to events specified in other bits in this register. This field is set after a hardware or software reset.
D30	R/W	OC	0b	**Ownership change** 0 Ignore 1 Disable interrupt generation due to ownership change.
D29:07	N/A	Reserved	N/A	N/A
D06	R/W	RHSC	0b	**Root hub status change** 0 Ignore 1 Disable interrupt generation due to root hub status change.
D05	R/W	FNO	0b	**Frame number overflow** 0 Ignore 1 Disable interrupt generation due to frame number overflow.
D04	R/W	UE	0b	**Unrecoverable error** 0 Ignore 1 Disable interrupt generation due to unrecoverable error.

Table 448: HcInterruptDisable register

Bits	Access	Mnemonic	Reset	Description
D03	R/W	RD	0b	**Resume detect** 0 Ignore 1 Disable interrupt generation due to resume detect.
D02	R/W	SF	0b	**Start of frame** 0 Ignore 1 Disable interrupt generation due to start of frame.
D01	R/W	WDH	0b	**HcDoneHead writeback** 0 Ignore 1 Disable interrupt generation due to HcDoneHead writeback.
D00	R/W	SO	0b	**Scheduling overrun** 0 Ignore 1 Disable interrupt generation due to scheduling overrun.

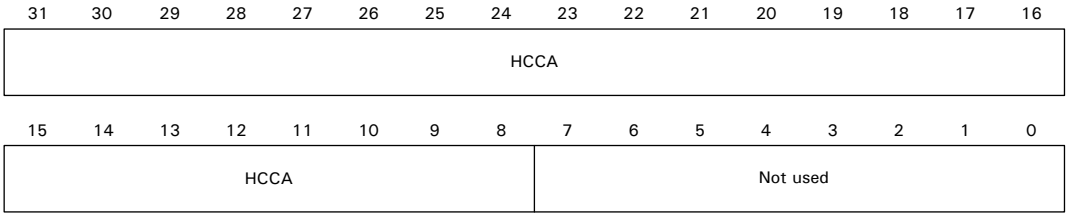
Table 448: HcInterruptDisable register

HcHCCA register

Address: 9010 1018

The HcHCCA register contains the physical address of the host controller communication area (HCCA), which is a RAM area with a defined format. The host controller driver determines the alignment restrictions by writing all 1s to HcHCCA and reading the content of HcHCCA. The alignment is evaluated by examining the number of zeros in the lower order bits. The minimum alignment is 256 bytes; bits 0 through 7, then, must always return 0 when read.

The host controller communication area holds the control structures and the interrupt table that are accessed by both the host controller and the host controller driver.



Register bit assignment

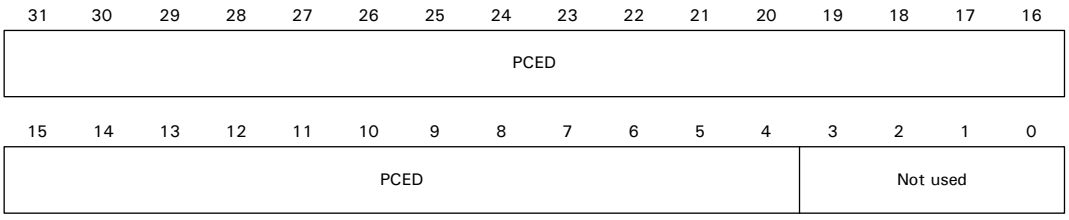
Bits	Access	Mnemonic	Reset	Description
D31:08	R/W	HCCA	0h	Base address of the host controller communication area.
D07:00	R/W	Not used	0	Must be written to 0.

Table 449: HcHCCA register

HcPeriodCurrentED register

Address: 9010 101C

The HcPeriodCurrentED register contains the physical address of the current isochronous or interrupt endpoint descriptor.



Register bit assignment

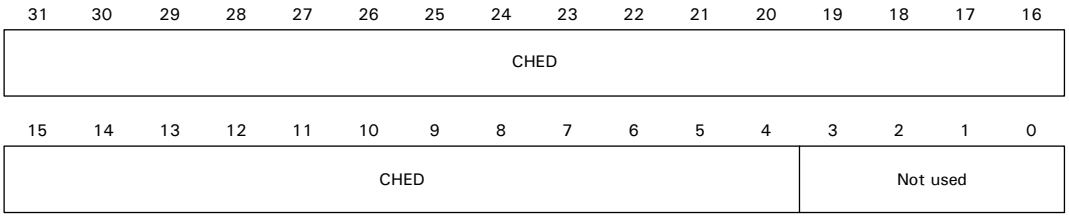
Bits	Access	Mnemonic	Reset	Description
D31:04	R	PCED	0h	**PeriodCurrentED** Used by the host controller to point to the head of one of the periodic lists that will be processed in the current frame. The content of this register is updated by the host controller after a periodic endpoint has been processed. The host controller driver can read the content to determine which endpoint currently is being processed at the time of the reading.
D03:00	N/A	Not used	0	Must be written to 0.

Table 450: HcPeriodCurrentED

HcControlHeadED register

Address: 9010 1020

The HcHeadControlED register contains the physical address of the first endpoint descriptor of the control list.



Register bit assignment

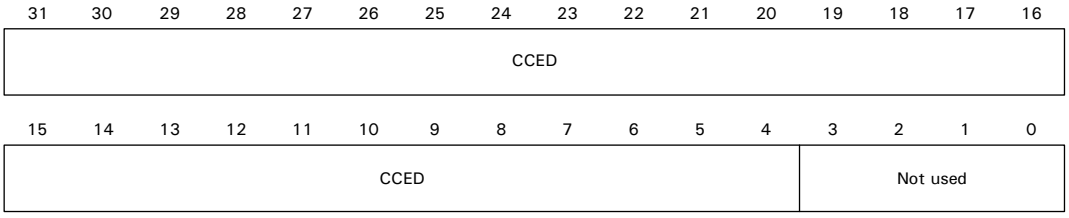
Bits	Access	Mnemonic	Reset	Description
D31:04	R/W	CHED	0h	**ControlHeadED** The host controller traverses the control list starting with the HcCOntrolHeadED pointer. The content is loaded from the host controller communication area during the host controller initialization.
D03:00	N/A	Not used	0	Must be written to 0.

Table 451: HcControlHeadED register

HcControlCurrentED register

Address: 9010 1024

The HcControlCurrentED register contains the physical address of the control list's current endpoint descriptor.



Register bit assignment

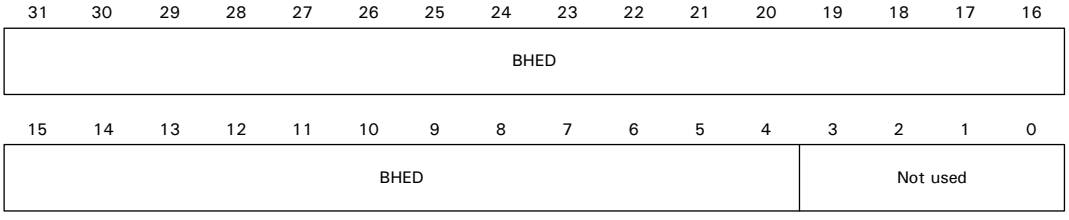
Bits	Access	Mnemonic	Reset	Description
D31:04	R/W	CCED	0h	**ControlCurrentED** This pointer is advanced to the next endpoint descriptor after serving the present one. The host controller continues processing the list from where it left off in the last frame. When it reaches the end of the control list, the host controller checks the ControlListFilled field (see "HcCommandStatus register," beginning on page 747). If the ControlListFilled field is set, the host controller copies the content of the HcControlHeadED register to this register and clears the bit. If the ControlListFilled field is not set, the host controller does nothing. The host controller driver is allowed to modify this register only when the ControlListEnable field (see "HcControl register," beginning on page 743) is cleared. When the ControlListEnable field is set, the host controller driver only reads the instantaneous value of this register. Initially, this value is set to zero to indicate the end of the control list.
D03:00	N/A	Not used	0	Must be written to 0.

Table 452: HcControlCurrentED register

HcBulkHeadED register

Address: 9010 1028

The HcBulkHeadED register contains the physical address of the first endpoint descriptor of the bulk list.



Register bit assignment

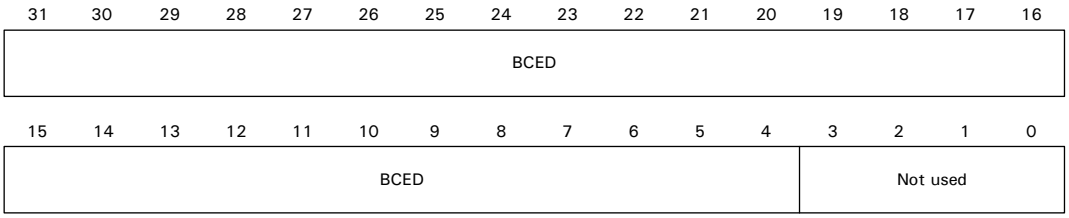
Bits	Access	Mnemonic	Reset	Description
D31:04	R/W	BHED	0h	BulkHeadED The host controller traverses the bulk list starting with the HcBulkHeadED pointer. The content is loaded from the host controller communication area during the host controller initialization.
D03:00	N/A	Not used	0	Must be written to 0.

Table 453: HcBulkHeadED register

HcBulkCurrentED register

Address: 9010 102C

The HcBulkCurrentED register contains the physical address of the bulk list's current endpoint. As the bulk list will be served in round-robin fashion, the endpoints will be ordered according to their insertion in the list.



Register bit assignment

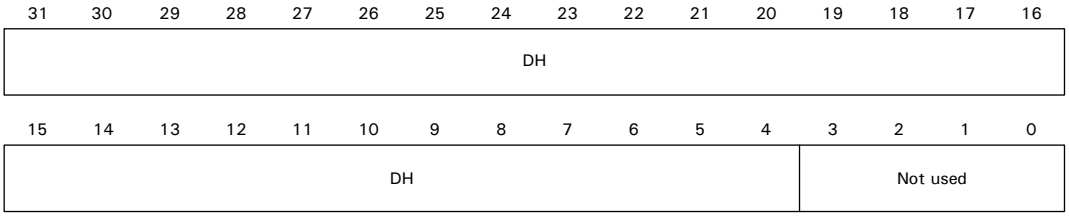
Bits	Access	Mnemonic	Reset	Description
D31:04	R/W	BCED	0h	**BulkCurrentED** BulkCurrentED is advanced to the next endpoint descriptor after the host controller has served the present endpoint descriptor. The host controller continues processing the list from where it left off in the last frame. When it reaches the end of the bulk list, the host controller checks the ControlListFilled field (see "HcControl register," beginning on page 743). If ControlListFIlled is set, the host controller copies the content of HcBulkHeadED to HcBulkCurrentED and clears the bit. If ControlListFilled is not set, the host controller does nothing. The host controller driver is allowed to modify this register only when the BulkListEnable field (see "HcControl register," beginning on page 743) is cleared. When BulkListEnable is set, the host control driver only reads the instantaneous value of this register. This value initially is set to zero to indicate the end of the bulk list.
D03:00	N/A	Not used	0	Must be written to 0.

Table 454: HcBulkCurrentED register

HcDoneHead register

Address: 9010 1030

The HcDoneHead register contains the physical address of the last completed transfer descriptor that was added to the Done queue. In normal operation, the host controller driver should not need to read this register as its content is written periodically to the host controller communication area.



Register bit assignment

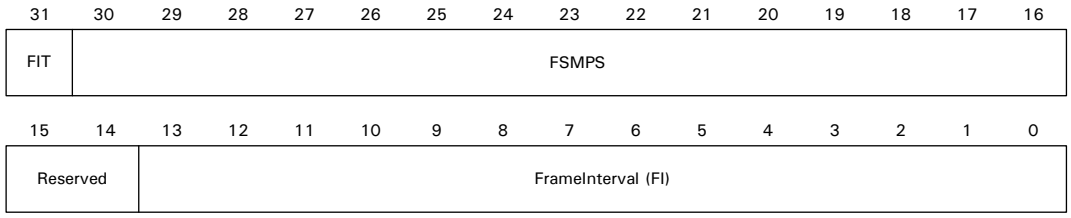
Bits	Access	Mnemonic	Reset	Description
D31:04	R	DH	0h	**DoneHead** When a TD is completed, the host controller writes the content of HcDoneHead to the NextTD field of the TD. The host controller then overwrites the content of HcDoneHead with the address of this TD. This value is written to zero whenever the host controller writes the content of this register to the host controller communications area. It also sets the WritebackDoneHead of the HcInterruptStatus register (see "HcInterruptStatus register," beginning on page 750).
D03:00	N/A	Not used	0	Must be written to 0.

Table 455: HcDoneHead register

HcFmInterval register

Address: 9010 1034

The HcFmInterval register contains the 14-bit value that indicates the bit time interval in a frame (that is, between two consecutive SOFs), and a 15-bit value indicating the full speed maximum packet size that the host controller can transmit or receive without causing a scheduling overrun. The host controller driver can perform minor adjustment on the FrameInterval by writing a new value over the present one at each SOF. This provides the programmability necessary for the host controller to synchronize with an external clocking resource and to adjust any unknown local clock offset.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31	R/W	FIT	0b	**FrameIntervalToggle** The host controller driver toggles this bit whenever it loads a new value to FrameInterval.
D30:16	R/W	FSMPS	0	**FSLargestDataPacket** Specifies a value that is loaded into the largest data packet counter at the beginning of each frame. The counter value represents the largest amount of data, in bits, that can be sent to received by the host controller in a single transaction, at any given timer, without causing scheduling overrun. The field value is calculated by the host controller driver.
D15:14	N/A	Reserved	N/A	N/A

Table 456: HcFmInterval register

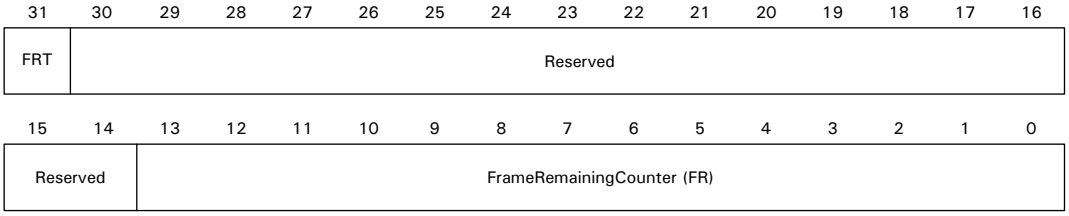
Bits	Access	Mnemonic	Reset	Description
D13:00	R/W	FI	2EDFh	**FrameInterval** Specifies the interval between two consecutive SOFs in bit times. The nominal value is 11,999. The host controller driver should store the current value of this field before resetting the host controller using the HostControllerReset field in the HcCommandStatus register (see "HcCommandStatus register," beginning on page 747), as this causes the host controller to reset this field to its nominal value. The host controller driver optionally can restore the stored value when the reset sequence completes.

Table 456: HcFmInterval register

HcFmRemaining register

Address: 9010 1038

The HcFmRemaining register is a 14-bit down counter showing the bit time remaining in the current frame.



Register bit assignment

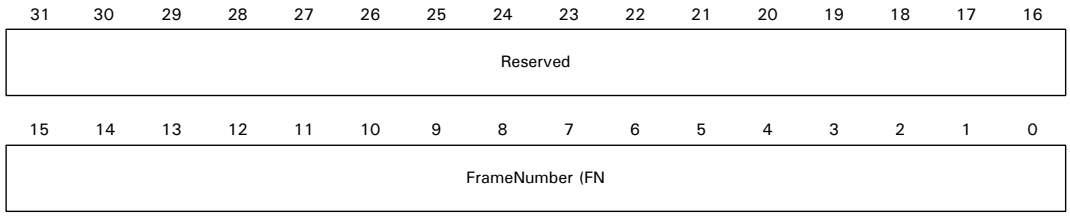
Bits	Access	Mnemonic	Reset	Description
D31	R	FRT	0b	**FrameRemainingToggle** Loaded from the FrameIntervalToggle field of the HcFmInterval register (see "HcFmInterval register" on page 764) when FrameRemaining (D13:00 in this register) reaches 0. This bit is used by HCD for synchronization between FrameInterval and FrameRemaining.
D30:14	N/A	Reserved	N/A	N/A
D13:00	R	FR	0h	**FrameRemaining counter** Decremented at each bit time. When the counter reaches zero, it is reset by loading the FrameInterval value specified in the HcFrameInterval register (see "HcFmInterval register" on page 764) at the next bit time boundary.

Table 457: HcFmRemaining register

HcFmNumber register

Address: 9010 103C

The HcFmNumber register is a 16-bit counter that provides a timing reference among events happening in the host controller driver. The host controller driver can use the 16-bit value specified in this register and generate a 32-bit frame number without requiring frequent access to the register.



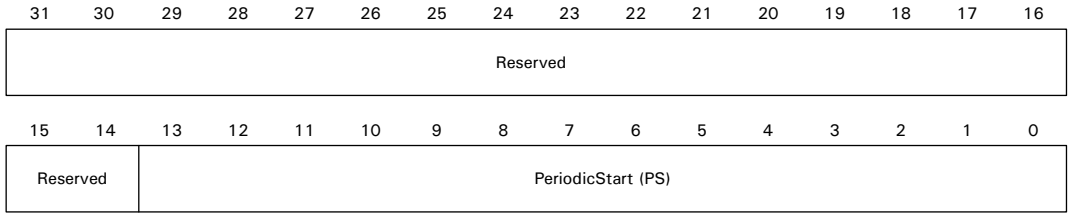
Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:16	N/A	Reserved	N/A	N/A
D15:00	R	FN	0h	**FrameNumber** Incremented when the HcFmRemaining register (see "HcFmRemaining register" on page 765) is reloaded. The frame number will be rolled over to 0h after ffffh. When entering the USB operational state, FrameNumber is incremented automatically. The content is written to HCCA after the host controller has incremented FrameNumber at each frame boundary and sent a SOF but before HC reads the first endpoint descriptor in that frame. After writing to HCCa, the host controller sets the StartofFrame field in the HcInterruptStatus register (see "HcInterruptStatus register" on page 750).

Table 458: HcFmNumber register

HcPeriodicStart register

Address: 9010 1040



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:14	N/A	Reserved	N/A	N/A

Table 459: HcPeriodicStart register

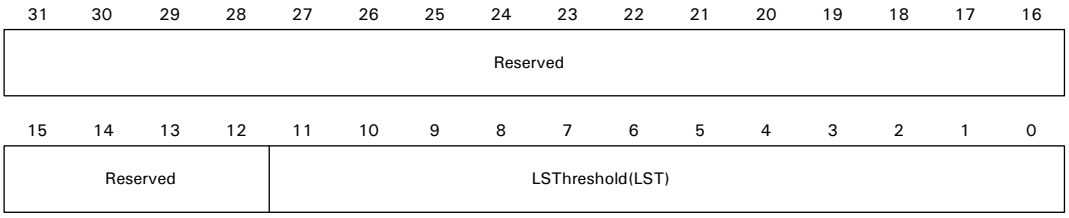
Bits	Access	Mnemonic	Reset	Description
D13:00	R/W	PS	0h	**PeriodicStart** Determines when is the earliest time the host controller should start processing the periodic list. After a hardware reset, the PS field is cleared. The field is then set by the host controller driver during the host controller initialization. The value is calculated as approximately 10% off from the FrameInterval. A typical value is 3E67h. When FrameRemaining reaches the value specified, processing the periodic lists will have priority over control/bulk processing. The host controller starts processing the interrupt list after completing the current control or bulk transaction in progress.

Table 459: HcPeriodicStart register

HcLsThreshold register

Address: 9010 1044

The HcLSThreshold register contains a value used by the host controller to determine whether to commit to the transfer of a maximum-of-8-byte LS packet before EOF. Neither the host controller driver not the host controller is allowed to change this value.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:12	N/A	Reserved	N/A	N/A
D11:00	R/W	LST	0628h	**LSThreshold** Contains a value that is compared to the FrameRemaining field before initiating a low speed (LS) transaction. The transaction is started only if FrameRemaining is greater than or equal to LSThreshold. The value is calculated by the host controller driver, with transmission and setup overhead considerations.

Table 460: HcLsThreshold register

Root hub partition registers

The remaining USB host block registers are dedicated to the USB root hub, which is an integral part of the host controller although it is a functionally separate entity. The host controller driver emulates USBD accesses to the root hub through a register interface. The host controller driver maintains many USB-defined hub features that are not required to be supported in hardware; for example, the hub's device configuration, interface, and endpoint descriptors are maintained only in the host controller driver as well as some status fields of the class descriptor. The host controller driver also maintains and decodes the root hub's device address as well as performs other operations that are better suited to software than hardware.

The root hub register interface maintains similarity of bit organization and operation to typical hubs that are found in the system. The four registers defined in this section are each read and written as 32 bits. These registers are written only during initialization to correspond with system implementation.

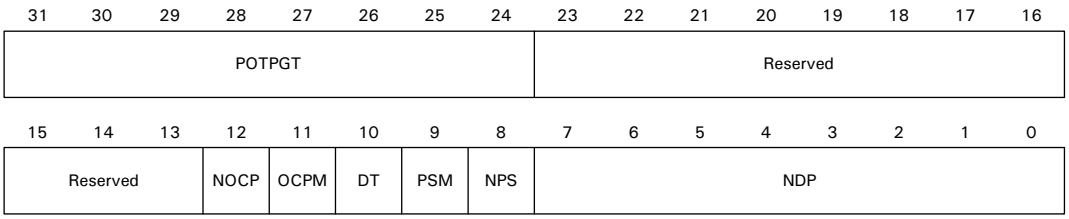
- The HcRhDescriptor A and HcRhDescriptorB registers should be implemented to be writeable, regardless of the host controller USB state.
- The HcRhStatus register and HcRhPortStatus register must be writeable during the USB operational state.

Note: *IS* denotes an *implementation-specific* reset value for the related field.

HcRhDescriptorA register

Address: 9010 1048

The HcRhDescriptorA register is the first of two registers describing the characteristics of the *root hub*. The root hub is the logical hub built into a USB host. Reset values are implementation-specific.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:24	R/W	POTPGT	IS	**PowerOnToPowerGoodTime** Specifies the length of time the host controller driver has to wait before accessing a powered-on port of the root hub. The unit of time is 2 ms. The duration is calculated as `POTPGT*2 ms`.
D23:13	N/A	Reserved	N/A	N/A
D12	R/W	NOCP	IS	**NoOverCurrentProtection** Describes how the overcurrent status for the root hub ports is reported. When the NOCP bit is cleared, the OverCurrentProtectionMode field (D11 in this register) specifies global or per-port reporting: 0 Overcurrent status is reported collectively for all downstream ports. 1 No overcurrent protection supported.

Table 461: HcRhDescriptorA register

Bits	Access	Mnemonic	Reset	Description
D11	R/W	OCPM	IS	**OverCurrentProtectionMode** Describes how the overcurrent status for the root hub ports is reported. At reset, this field should reflect the same mode as PowerSwitchingMode (D08 in this register). The OCPM field is valid only if the NoOverCurrentProtection field (D12 in this register) is cleared. 0 Overcurrent status is reported collectively for all downstream ports. 1 Overcurrent status is reported on a per-port basis.
D10	R	DT	0b	**Device type** Specifies that the root hub is not a compound device. The root hub is not allowed to be a compound device. This field should always read 0.
D09	R/W	PSM	IS	**PowerSwitchingMode** Specifies how the power switching of the root hubs is controlled. This field is valid only if the NoPowerSwitching field (D08 in this register) is cleared. 0 All ports are powered at the same time. 1 Each port is powered individually. This mode allows port power to be controlled by either the global switch or per-port switching. If the PortPowerControlMask bit (see "HcRhDescriptorB register" on page 772) is set, the port responds only to port power commands (Set/ClearPortPower). If the port mask is cleared, the port is controlled only by the global power switch (Set/ ClearGlobalPower).
D08	R/W	NPS	IS	**NoPowerSwitching** Specifies whether power switching is supported or ports are always powered. When this bit is cleared, the PowerSwitchingMode (D09 in this register) specifies global or per-port switching. 0 Ports are power switched. 1 Ports are always powered on when the host controller is powered on.

Table 461: HcRhDescriptorA register

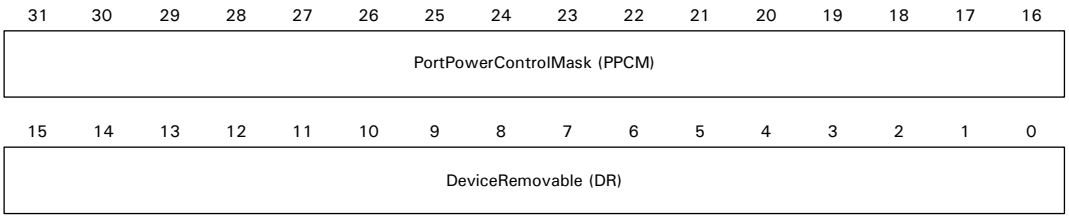
Bits	Access	Mnemonic	Reset	Description
D07:00	R	NDP	IS	**NumberDownstreamPorts** Specifies the number of downstream ports supported by the root hub. The minimum number of ports is 1; the maximum number of ports supported is 15.

Table 461: HcRhDescriptorA register

HcRhDescriptorB register

Address: 9010 104C

The HcRhDescriptorB register is the second of two registers describing the characteristics of the root hub. These fields are written during initialization to correspond with the system implementation. Reset values are implementation-specific.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:16	R/W	PPCM	IS	**PortPowerControlMask** Each bit indicates whether a port is affected by a global control command when PowerSwitchingMode (see "HcRhDescriptorA register" on page 770) is set. When set, the port's power state is affected only by per-port power control (Set/ClearPortPower). When cleared, the port is controlled by the global power switch (Set/ClearGlobalPower). If the device is configured to global switching mode (PowerSwitchingMode = 0), this field is not valid. Bit 0: Reserved Bit 1: Ganged-power mask on port #1 Bit 2: Ganged-power mask on port #2 ... Bit 15: Ganged-power mask on port #15
D15:00	R/W	DR	IS	**DeviceRemovable** Each bit is dedicated to a root hub port. ■ When cleared, the attached device is removable. ■ When set, the attached device is not removable. Bit 0: Reserved Bit 1: Device attached to port #1 Bit 2: Device attached to port #2 ... Bit 15: device attached to port #15

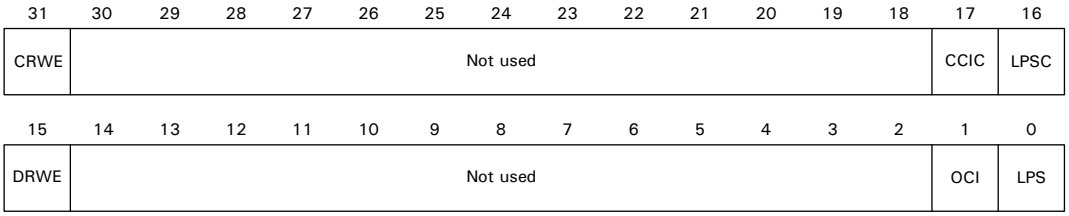
Table 462: HcRhDesdcriptorB register

HcRhStatus register

Address: 9010 1050

The HcRhStatus register has two parts:

- The lower word of a Dword represents the *hub status* field.
- The upper word of the Dword represents the *hub status change* field.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31	W	CRWE	N/A	**ClearRemoteWakeupEnable** 0 Has no effect 1 Clears DeviceRemoveWakeupEnable
D30:18	N/A	Not used	N/A	Always write to 0.
D17	R/W	CCIC	0b	**OverCurrentIndicatorChange** Set by hardware when a change has occurred to the OCI field (bit 01 in this register). The host controller driver clears this bit by writing 1. Writing 0 to this bit has no effect.
D16	R/W	LPSC	0b	**LocalPowerStatusChange (LPSC)** Not supported; always read as 0. **SetGlobalPower (write)** In global power mode (PowerSwitchingMode = 0), this bit is written to 1 to turn on power to all ports (clear PowerPortStatus). ■ In per-port mode, this bit sets PortPowerStatus only on ports whose PortPowerControlMask bit is not set. ■ Writing 0 to this bit has no effect

Table 463: HcRhStatus register

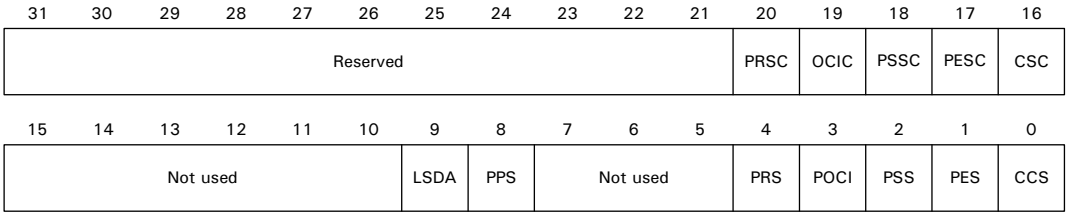
Bits	Access	Mnemonic	Reset	Description
D15	R/W	DRWE	0b	**DeviceRemoteWakeupEnable (read)** Enables a ConnectStatusChange bit as a resume event, causing a USBSUSPEND or USBRESUME state transition and setting the ResumeDetected interrupt. 0 ConnectStatusChange is not a remote wakeup event 1 ConnectStatusChange is a remote wakeup event. **SetRemoteWakeupEnable (write)** 0 Has no effect 1 Sets DeviceRemoteWakeupEnable
D14:02	N/A	Not used	N/A	Always write to 0.
D01	R	OCI	0b	**OverCurrentIndicator** Reports overcurrent conditions when global reporting is implemented. ■ When set, an overcurrent condition exists. ■ When cleared, all power operations are normal. If per-port overcurrent is implemented, this bit is always 0.
D00	R/W	LPS	0b	**LocalPowerStatus (read)** Not supported; always read as 0. **ClearGlobalPower (write)** In global power mode (PowerSwitchingMode = 0), this bit is always written to 1 to turn off power to all ports (clear PowerPortStatus). In per-port power mode, this bit clears PortPowerStatus only on ports whose PortPowerControlMask bit is not set. Writing 0 to this bit has no effect.

Table 463: HcRhStatus register

HcRhPortStatus[1] register

Address: 9010 1054

The HcRhPortStatus register controls and reports port events on a per-port basis. The lower word reflects port status; the upper word reflects the status change bits. If a transaction (token through handshake) is in progress when a write to change port status occurs, the resulting port status change must be postponed until the transaction completes.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:21	N/A	Not used	N/A	Always write to 0.
D20	R/W	PRSC	0b	**PortResetStatusChange** 0 Port reset is not complete 1 Port reset is complete Set at the end of the 10-ms port reset signal. The host controller driver writes a 1 to clear this bit. Writing 0 has no effect.
D19	R/W	OCIC	0b	**PortOverCurrentIndicatorChange** 0 No change in PortOverCurrentIndicator 1 PortOverCurrentIndicator has changed Valid only if overcurrent conditions are reported on a per-port basis. This bit is set when root hub changes the PortOverCurrentIndicator bit. The host controller driver writes a 1 to clear this bit. Writing 0 has no effect.

Table 464: HcRhPortStatus[1] register

Bits	Access	Mnemonic	Reset	Description
D18	R/W	PSSC	0b	**PortSuspendStatusChange** 0 Resume is not completed 1 Resume completed Set when the full resume sequence has been completed. This sequence includes the 20-s resume pulse, LS EOP, and 3-ms resynchronization delay. The host controller driver writes a 1 to clear this bit. Writing 0 has no effect. This bit also is cleared when ResetStatusChange is set.
D17	R/W	PESC	0b	**PortEnableStatusChange** 0 No change in PortEnableStatus 1 Change in PortEnableStatus Set when hardware events cause the PortEnableStatus bit to be cleared. Changes from host controller driver writes do not set this bit. The host controller driver writes a 1 to clear this bit. Writing 0 has no effect.
D16	R/W	CSC	0b	**ConnectStatusChange** 0 No change in CurrentConnectStatus 1 Change in CurrentConnectStatus Set when a connect or disconnect event occurs. The host controller driver writes a 1 to clear this bit. Writing 0 has no effect. If CurrentConnectStatus is cleared when a SetPortReset, SetPortEnable, or SetPortSuspend write occurs, this bit is set to force the driver to re-evaluate the connection status, as these writes should not occur if the port is disconnected. **Note:** If the DeviceRemovable[NDP] bit is set, the CSC bit is set only after a root hub reset, to tell the system that the device is attached.
D15:10	N/A	Not used	N/A	Always write to 0.

Table 464: HcRhPortStatus[1] register

Bits	Access	Mnemonic	Reset	Description
D09	R/W	LSDA	Xb	**LowSpeedDeviceAttached (read)** 0 Full speed device attached 1 Low speed device attached Indicates the speed of the device attached to this port. When set, the low speed device is attached to this port. When clear, a full speed device is attached to this port. This field is valid only when CurrentConnectStatus is set. **ClearPortPower (write)** The host controller driver clears the PortPowerStatus bit by writing a 1 to this bit. Writing 0 has no effect.
D08	R/W	PPS	0b	**PortPowerStatus (read)** 0 Port power is off 1 Port power is on Reflects the port's power status, regardless of the type of power switching implemented. This bit is cleared is an overcurrent condition is found. The host controller driver sets this bit by writing SetPortPower or SetGlobalPower. The host controller driver clears this bit by writing ClearPortPower or ClearGlobalPower. PowerSwitchingMode and PortPowerControlMask determine which switches are enabled. ■ In global switching mode, (PowerSwitchingMode = 0), only Set/ClearGlobalPower controls this bit. ■ In per-port power switching (PowerSwitchingMode = 1), if the PortPowerControlMask bit is set, only Set/ClearPortPower commands are enabled. If the mask is not set, only Set/ClearGlobalPower commands are enabled. When port power is disabled, CurrentConnectStatus, PortEnableStatus, PortSuspendStatus, and PortResetStatus should be reset.

Table 464: HcRhPortStatus[1] register

Bits	Access	Mnemonic	Reset	Description
D08 *(cont)*	R/W	PPS	0b	**SetPortPower (write)** The host controller driver writes a 1 to set the PortPowerStatus bit. Writing a 0 has no effect. **Note:** This bit always reads 1b if power switching is not supported.
D07:05	N/A	Not used	N/A	Always write to 0.
D04	R/W	PRS	0b	**PortResetStatus (read)** 0 Port reset signal is not active 1 Port reset signal is active When this bit is set by a write to SetPortReset, port reset signalling is asserted. When reset is completed, this bit is cleared when PortResetStatusChange is set. This bit cannot be set if CurrentConnectStatus is cleared. **SetPortReset (write)** The HCD sets the port reset signalling by writing a 1 to this bit. Writing 0 has no effect. If CurrentConnectStatus is cleared, this write does not set PortResetStatus; it sets ConnectStatusChange, which tells the driver that it tried to reset a disconnected port.
D03	R/W	POCI	0b	**PortOverCurrentIndicator (read)** 0 No overcurrent condition 1 Overcurrent condition found Valid only when the root hub is configured such that overcurrent conditions are reported on a per-port basis. If per-port overcurrent reporting is not supported, this bit is set to 0. If cleared, all power operations are normal for this port. If set, an overcurrent condition exists on this port. This bit always reflects the overcurrent input signal. **ClearSuspendedStatus (write)** The host controller driver writes a 1 to initiate a resume. Writing 0 has no effect. A resume is initiated only if PortSuspendStatus is set.

Table 464: HcRhPortStatus[1] register

Bits	Access	Mnemonic	Reset	Description
D02	R/W	PSS	0b	**PortSuspendStatus (read)** 0 Port is not suspended 1 Port is suspended Indicates that the port is suspended or in the resume sequence. This bit is set by a SetSuspendState write and cleared when PortSuspendStatusChange is set at the end of the resume interval. This bit cannot be set if CurrentConnectStatus is cleared. This bit is cleared when PortResetStatusChange is set at the end of the port reset or when the host controller is placed in the USBRESUME state. If an upstream resume is in progress, it should propagate to the host controller. **SetPortSuspend (write)** The host controller driver sets PortEnableStatus by writing a 1. Writing a 0 has no effect. If CurrentConnectStatus is cleared, this write does not set PortSuspendStatus; it sets ConnectStatusChange, which tells the driver that it tried to suspend a disconnected port.

Table 464: HcRhPortStatus[1] register

Bits	Access	Mnemonic	Reset	Description
D01	R/W	PES	0b	**PortEnableStatus (read)** 0 Port is disabled 1 Port is enabled Indicates whether the port is enabled or disabled. The NS9775 can clear this bit when an overcurrent condition, disconnect event, switched-off power, or operational bus error (such as babble) is found. This change also causes PortEnableStatusChange (bit 17 in this register) to be set. The host controller driver sets this bit by writing SetPortEnable and clears the bit by writing ClearPortEnable. This bit cannot be set when CurrentConnectStatus is cleared. This bit is also set, if not already done, at the completion of a port reset when ResetStatusChange is set or port suspend when SuspendStatusChange is set. **SetPortEnable (write)** Sets PortEnableStatus by writing a 1. Writing 0 has no effect. If CurrentCOnnectStatus is cleared, this write does not set PortEnableStatus; it sets ConnectStatusChange, which tells the driver that it tried to enable a disconnected port.
D00	R/W	CCS	0b	**CurrentConnectStatus (read)** Reflects the current state of the downstream port. 0 No device connected 1 Device connected **ClearPortEnable (write)** The host controller driver writes a 1 to this bit to clear the PortStatusEnable bit. Writing a 0 has no effect. The CurrentConnectStatus is not affected by any write. **Note:** This bit is always read as 1b when the attached device is non-removable (DeviceRemovable[NDP]).

Table 464: HcRhPortStatus[1] register

USB Device Block registers

Table 465 provides the addresses of the USB Device Block registers.

Address	Register
9010 2000	Device Descriptor/Setup Command register
9010 2004	Endpoint Descriptor #0
9010 2008	Endpoint Descriptor #1
9010 200C	Endpoint Descriptor #2
9010 2010	Endpoint Descriptor #3
9010 2014	Endpoint Descriptor #4
9010 2018	Endpoint Descriptor #5
9010 201C	Endpoint Descriptor #6
9010 2020	Endpoint Descriptor #7
9010 2024	Endpoint Descriptor #8
9010 2028	Endpoint Descriptor #9
9010 202C	Endpoint Descriptor #10
9010 2030	Endpoint Descriptor #11

Table 465: USB Device Block registers address map

Device Descriptor/Setup Command register

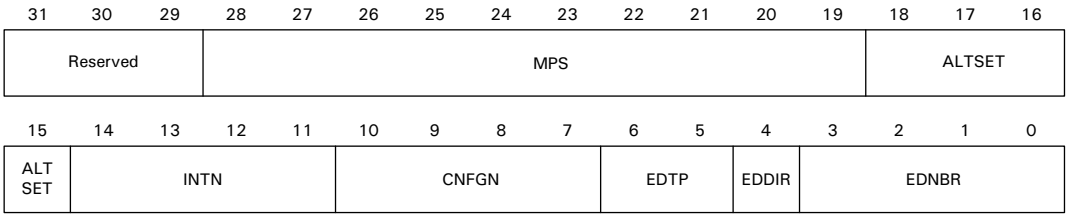
Address: 9010 2000

The Device Descriptor/Setup Command register is a legacy register. This register must be written to the value `0x0000_0100`.

Endpoint Descriptor #0–#11 registers

Address: 9010 2004 / 2008 / 200C / 2010 / 2014 / 2018 / 201C / 2020 / 2024 / 2028 / 202C / 2030

The Endpoint Descriptor registers store the endpoint information. There are 12 registers, one for each endpoint descriptor. Each register contains the same information for the endpoint descriptor.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:29	N/A	Reserved	N/A	N/A
D28:19	R/W	MPS	10'h0	Maximum packet size.
D18:15	R/W	ALTSET	4'h0	Alternate setting to which this endpoint belongs.
D14:11	R/W	INTN	4'h0	Interface number to which this endpoint belongs.
D10:07	R/W	CNFGN	4'h0	Configuration number to which this endpoint belongs. **Note:** Value at 0x0 is not supported if dynamic programming is enabled (CSRPRG set to 1 in the Device IP Programming Control and Status register).
D06:05	R/W	EDTP	2'h0	**Endpoint type** 00 Control 01 Isochronous 10 Bulk 11 Interrupt

Table 466: Endpoint Descriptor register (for endpoint descriptors 0–11)

Bits	Access	Mnemonic	Reset	Description
D04	R/W	EDDIR	1h'0	**Endpoint direction** 0 Out 1 In
D03:00	R/W	EDNBR	4'h0	Endpoint number

Table 466: Endpoint Descriptor register (for endpoint descriptors 0–11)

USB Device Endpoint FIFO Control and Data registers

Table 467 provides the addresses for the endpoint registers found in the application logic that interfaces to the USB device block.

Address	Register
9010 3000	FIFO Interrupt Status 0
9010 3004	FIFO Interrupt Enable 0
9010 3010	FIFO Interrupt Status 1
9010 3014	FIFO Interrupt Enable 1
9010 3020	FIFO Interrupt Status 2
9010 3024	FIFO Interrupt Enable 2
9010 3030	FIFO Interrupt Status 3
9010 3034	FIFO Interrupt Enable 3
9010 3080	FIFO Packet Control #1
9010 3084	FIFO Packet Control #2
9010 3088	FIFO Packet Control #3
9010 308C	FIFO Packet Control #4
9010 3090	FIFO Packet Control #5
9010 3094	FIFO Packet Control #6

Table 467: USB Device Endpoint FIFO Control registers address map

Address	Register
9010 3098	FIFO Packet Control #7
9010 309C	FIFO Packet Control #8
9010 30A0	FIFO Packet Control #9
9010 30A4	FIFO Packet Control #10
9010 30A8	FIFO Packet Control #11
9010 30AC	FIFO Packet Control #12
9010 30B0	FIFO Packet Control #13
9010 3100	FIFO Status and Control #1
9010 3108	FIFO Status and Control #2
9010 3110	FIFO Status and Control #3
9010 3118	FIFO Status and Control #4
9010 3120	FIFO Status and Control #5
9010 3128	FIFO Status and Control #6
9010 3130	FIFO Status and Control #7
9010 3138	FIFO Status and Control #8
9010 3140	FIFO Status and Control #9
9010 3148	FIFO Status and Control #10
9010 3150	FIFO Status and Control #11
9010 3158	FIFO Status and Control #12
9010 3160	FIFO Status and Control #13

Table 467: USB Device Endpoint FIFO Control registers address map

Table 468 describes the *fixed* relationship from endpoint to interface FIFO to DMA channel for all registers described in the remainder of the chapter.

DMA channel	FIFO	EP number
1	1	0 (CTRL-Out)
2	2	0 (CTRL-In)

Table 468: FIFO to DMA channel to endpoint map

DMA channel	FIFO	EP number
3	3	1
4	4	2
5	5	3
6	6	4
7	7	5
8	8	6
9	9	7
10	10	8
11	11	9
12	12	10
13	13	11

Table 468: FIFO to DMA channel to endpoint map

FIFO Interrupt Status registers

The FIFO Interrupt Status registers contain interrupt status information for the device block FIFOs. All status bits are active high (1) and all interrupts are cleared by writing a 1 to the appropriate field.

Note: For diagnostic purposes, each of the interrupt status bits can be set by writing a 1 when the bits are at 0.

All FIFO status bits operate in a *catch and hold* mode, which means that once a status bit is set, it can be cleared only by writing a 1 to the corresponding bit position. If the status generating condition is present after writing a 1, the appropriate status bit is reasserted immediately.

Note: The NS9775 FIFO Interrupt Status registers pertain to DMA mode only; direct, or processor-controlled, mode is not supported at this time. The following control signals are considered “don’t care” signals, as they are valid only in direct mode: FULL, EMPTY, HALF, OFLOW, and UFLOW.

Device endpoint status

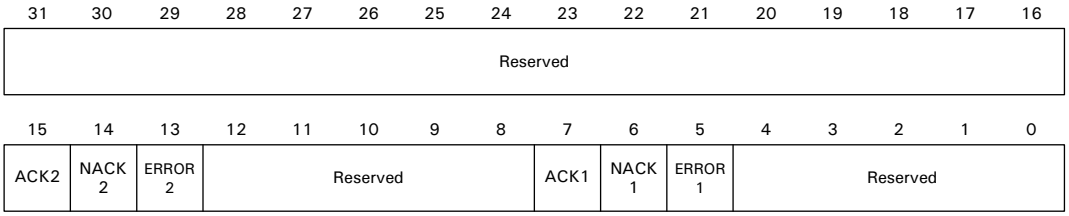
Table 469 defines the device endpoint status provided for each endpoint FIFO. Firmware uses this information to know which endpoints are active and whether there were any transmission errors.

Status	Direction	Description
ACK	In	Set when an ACK packet is received from the host in response to the previous data packet. For isochronous pipes, the ACK field is asserted automatically for each packet sent to the host.
NACK	In	Set when a NACK packet is sent to the host in response to the previous setup packet received from the host.
ERROR	In	Set when an ACK packet is not received from the host in response to the previous data packet sent to the host.
ACK	Out	Set when an ACK packet is sent to the host in response to the previous error-free packet received from the host. For isochronous pipes, this field is asserted automatically for each packet received from the host if the data is error-free.
NACK	Out	Set when a NACK packet is sent to the host in response to the previous setup packet received from the host.
ERROR	Out	Set when a packet is received from the host and a transmission error was found.

Table 469: USB device endpoint status

FIFO Interrupt Status 0 register

Address: 9010 3000



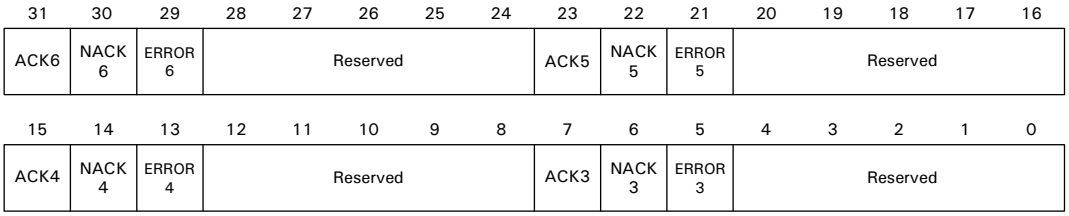
Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:16	N/A	Not used	0x0000	Always read as 0x0000.
D15	RW1TC	ACK2	0	Endpoint 0 (CTRL-In) acknowledge status. See Table 469, “USB device endpoint status,” on page 787.
D14	RW1TC	NACK2	0	Endpoint 0 (CTRL-In) negative acknowledge status. See Table 469, “USB device endpoint status,” on page 787.
D13	RW1TC	ERROR2	0	Endpoint 0 (CTRL-In) error status. See Table 469, “USB device endpoint status,” on page 787.
D12:08	N/A	Reserved	N/A	Not valid in DMA mode.
D07	RW1TC	ACK1	0	Endpoint 0 (CTRL-Out) acknowledge status. See Table 469, “USB device endpoint status,” on page 787
D06	RW1TC	NACK1	0	Endpoint 0 (CTRL-Out) negative acknowledge status. See Table 469, “USB device endpoint status,” on page 787.
D05	RW1TC	ERROR1	0	Endpoint 0 (CTRL-Out) error status. See Table 469, “USB device endpoint status,” on page 787.
D04:00	N/A	Reserved	N/A	Not valid in DMA mode.

Table 470: FIFO Interrupt Status 0 register

FIFO Interrupt Status 1 register

Address: 9010 3010



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31	RW1TC	ACK6	0	Endpoint 4 acknowledge status. See Table 469, “USB device endpoint status,” on page 787.
D30	RW1TC	NACK6	0	Endpoint 4 negative acknowledge status. See Table 469, “USB device endpoint status,” on page 787.
D29	RW1TC	ERROR6	0	Endpoint 4 error status. See Table 469, “USB device endpoint status,” on page 787.
D28:24	N/A	Reserved	N/A	Not valid in DMA mode.
D23	RW1TC	ACK5	0	Endpoint 3 acknowledge status. See Table 469, “USB device endpoint status,” on page 787.
D22	RW1TC	NACK5	0	Endpoint 3 negative acknowledge status. See Table 469, “USB device endpoint status,” on page 787.
D21	RW1TC	ERROR5	0	Endpoint 3 error status. See Table 469, “USB device endpoint status,” on page 787.
D20:16	N/A	Reserved	N/A	Not valid in DMA mode.
D15	RW1TC	ACK4	0	Endpoint 2 acknowledge status. See Table 469, “USB device endpoint status,” on page 787.
D14	RW1TC	NACK4	0	Endpoint 2 negative acknowledge status. See Table 469, “USB device endpoint status,” on page 787.

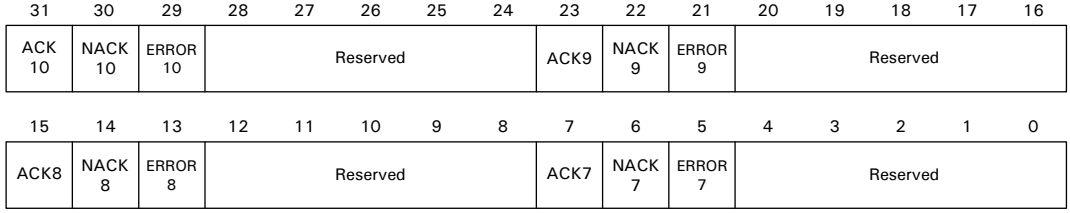
Table 471: FIFO Interrupt Status 1 register

Bits	Access	Mnemonic	Reset	Description
D13	RW1TC	ERROR4	0	Endpoint 2 error status. See Table 469, “USB device endpoint status,” on page 787.
D12:08	N/A	Reserved	N/A	Not valid in DMA mode.
D07	RW1TC	ACK3	0	Endpoint 1 acknowledge status. See Table 469, “USB device endpoint status,” on page 787.
D06	RW1TC	NACK3	0	Endpoint 1 negative acknowledge status. See Table 469, “USB device endpoint status,” on page 787.
D05	RW1TC	ERROR3	0	Endpoint 1 error status. See Table 469, “USB device endpoint status,” on page 787.
D04:00	N/A	Reserved	N/A	Not valid in DMA mode.

Table 471: FIFO Interrupt Status 1 register

FIFO Interrupt Status 2 register

Address: 9010 3020



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31	RW1TC	ACK10	0	Endpoint 8 acknowledges status. See Table 469, “USB device endpoint status,” on page 787.
D30	RW1TC	NACK10	0	Endpoint 8 negative acknowledgement status. See Table 469, “USB device endpoint status,” on page 787.
D29	RW1TC	ERROR10	0	Endpoint 8 error status. See Table 469, “USB device endpoint status,” on page 787.

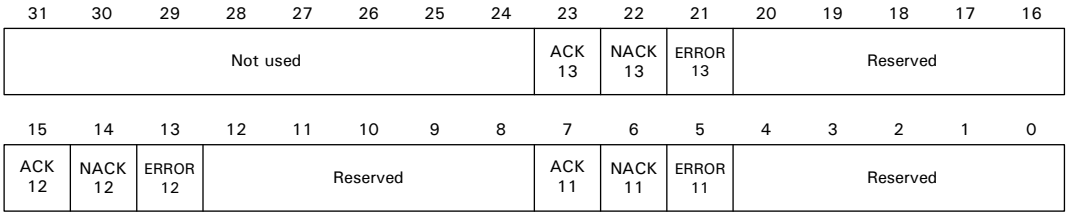
Table 472: FIFO Interrupt Status 2 register

Bits	Access	Mnemonic	Reset	Description
D28:24	N/A	Reserved	N/A	Not valid in DMA mode.
D23	RW1TC	ACK9	0	Endpoint 7 acknowledge status. See Table 469, “USB device endpoint status,” on page 787.
D22	RW1TC	NACK9	0	Endpoint 7 negative acknowledgement status. See Table 469, “USB device endpoint status,” on page 787.
D21	RW1TC	ERROR9	0	Endpoint 7 error status. See Table 469, “USB device endpoint status,” on page 787.
D20:16	N/A	Reserved	N/A	Not valid in DMA mode.
D15	RW1TC	ACK8	0	Endpoint 6 acknowledge status. See Table 469, “USB device endpoint status,” on page 787.
D14	RW1TC	NACK8	0	Endpoint 6 negative acknowledge status. See Table 469: "USB device endpoint status" on page 787.
D13	RW1TC	ERROR8	0	Endpoint 6 error status. See Table 469: "USB device endpoint status" on page 787.
D12:08	N/A	Reserved	N/A	Not valid in DMA mode.
D07	RW1TC	ACK7	0	Endpoint 5 acknowledge status. See Table 469: "USB device endpoint status" on page 787.
D06	RW1TC	NACK7	0	Endpoint 5 negative acknowledge status. See Table 469: "USB device endpoint status" on page 787.
D05	RW1TC	ERROR7	0	Endpoint 5 error status. See Table 469: "USB device endpoint status" on page 787.
D04:00	N/A	Reserved	N/A	Not valid in DMA mode.

Table 472: FIFO Interrupt Status 2 register

FIFO Interrupt Status 3 register

Address: 9010 3030



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:24	N/A	Not used	0x00	Always read as 0x00.
D23	RW1TC	ACK13	0	Endpoint 11 acknowledge status. See Table 469: "USB device endpoint status" on page 787.
D22	RW1TC	NACK13	0	Endpoint 11 negative acknowledge status. See Table 469: "USB device endpoint status" on page 787.
D21	RW1TC	ERROR13	0	Endpoint 11 error status. See Table 469: "USB device endpoint status" on page 787.
D20:16	N/A	Reserved	N/A	Not valid in DMA mode.
D15	RW1TC	ACK12	0	Endpoint 10 acknowledge status. See Table 469: "USB device endpoint status" on page 787.
D14	RW1TC	NACK12	0	Endpoint 10 negative acknowledge status. See Table 469: "USB device endpoint status" on page 787.
D13	RW1TC	ERROR12	0	Endpoint 10 error status. See Table 469: "USB device endpoint status" on page 787.
D12:08	N/A	Reserved	N/A	Not valid in DMA mode.
D07	RW1TC	ACK11	0	Endpoint 9 acknowledge status. See Table 469: "USB device endpoint status" on page 787.
D06	RW1TC	NACK11	0	Endpoint 9 negative acknowledge status. See Table 469: "USB device endpoint status" on page 787.

Table 473: FIFO Interrupt Status 3 register

Bits	Access	Mnemonic	Reset	Description
D05	RW1TC	ERROR11	0	Endpoint 9 error status. See Table 469: "USB device endpoint status" on page 787.
D04:00	N/A	Reserved	N/A	Not valid in DMA mode.

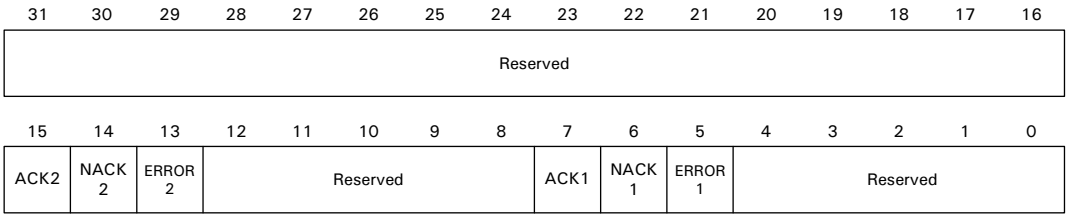
Table 473: FIFO Interrupt Status 3 register

FIFO Interrupt Enable registers

The FIFO Interrupt Enable registers contain the interrupt enable information for the device block FIFOs. All interrupts are enabled by writing a 1 and are disabled by writing a 0. The endpoint to register field mapping is identical to the FIFO Interrupt Status registers.

FIFO Interrupt Enable 0 register

Address: 9010 3004



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:16	N/A	Not used	0x0000	Always read as 0x0000.
D15	R/W	ACK2	0	Generate an interrupt when ACK2 in FIFO Interrupt Status 0 register is asserted.
D14	R/W	NACK2	0	Generate an interrupt when NACK2 in FIFO Interrupt Status 0 register is asserted.
D13	R/W	ERROR2	0	Generate an interrupt when ERROR2 in FIFO Interrupt Status 0 register is asserted.

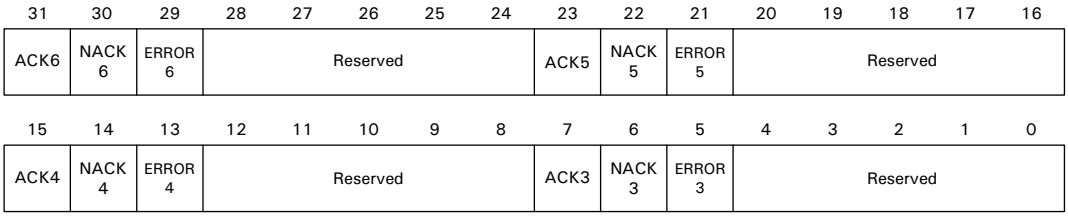
Table 474: FIFO Interrupt Enable 0 register

Bits	Access	Mnemonic	Reset	Description
D12:08	N/A	Reserved	N/A	Not valid in DMA mode.
D07	R/W	ACK1	0	Generate an interrupt when ACK1 in FIFO Interrupt Status 0 register is asserted.
D06	R/W	NACK1	0	Generate an interrupt when NACK1 in FIFO Interrupt Status 0 register is asserted.
D05	R/W	ERROR1	0	Generate an interrupt when ERROR1 in FIFO Interrupt Status 0 register is asserted.
D04:00	N/A	Reserved	N/A	Not valid in DMA mode.

Table 474: FIFO Interrupt Enable 0 register

FIFO Interrupt Enable 1 register

Address: 9010 3014



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31	R/W	ACK6	0	Generate an interrupt when ACK6 in FIFO Interrupt Status 1 register is asserted.
D30	R/W	NACK6	0	Generate an interrupt when NACK6 in FIFO Interrupt Status 1 register is asserted.
D29	R/W	ERROR6	0	Generate an interrupt when ERROR6 in FIFO Interrupt Status 1 register is asserted.
D28:24	N/A	Reserved	N/A	Not valid in DMA mode.
D23	R/W	ACK5	0	Generate an interrupt when ACK5 in FIFO Interrupt Status 1 register is asserted.

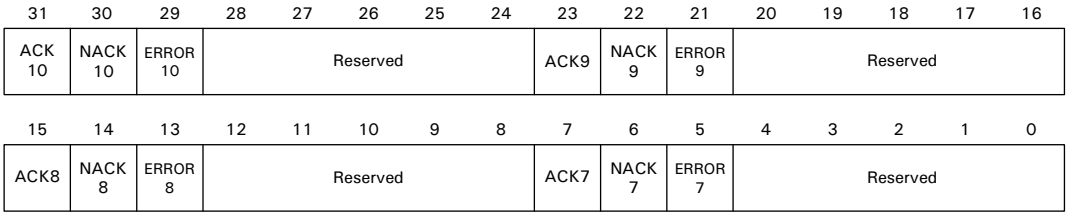
Table 475: FIFO Interrupt Enable 1 register

Bits	Access	Mnemonic	Reset	Description
D22	R/W	NACK5	0	Generate an interrupt when NACK5 in FIFO Interrupt Status 1 register is asserted.
D21	R/W	ERROR5	0	Generate an interrupt when ERROR5 in FIFO Interrupt Status 1 register is asserted.
D20:16	N/A	Reserved	N/A	Not valid in DMA mode.
D15	R/W	ACK4	0	Generate an interrupt when ACK4 in FIFO Interrupt Status 1 register is asserted.
D14	R/W	NACK4	0	Generate an interrupt when NACK4 in FIFO Interrupt Status 1 register is asserted.
D13	R/W	ERROR4	0	Generate an interrupt when ERROR4 in FIFO Interrupt Status 1 register is asserted.
D12:08	N/A	Reserved	N/A	Not valid in DMA mode.
D07	R/W	ACK3	0	Generate an interrupt when ACK3 in FIFO Interrupt Status 1 register is asserted.
D06	R/W	NACK3	0	Generate an interrupt when NACK3 in FIFO Interrupt Status 1 register is asserted.
D05	R/W	ERROR3	0	Generate an interrupts when ERROR3 in FIFO Interrupt Status 1 register is asserted.
D04:00	N/A	Reserved	N/A	Not valid in DMA mode.

Table 475: FIFO Interrupt Enable 1 register

FIFO Interrupt Enable 2 register

Address: 9010 3024



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31	R/W	ACK10	0	Generate an interrupt when ACK10 in FIFO Interrupt Status 2 register is asserted,
D30	R/W	NACK10	0	Generate an interrupt when NACK10 in FIFO Interrupt Status 2 register is asserted.
D29	R/W	ERROR10	0	Generate an interrupt when ERROR10 in FIFO Interrupt Status 2 register is asserted.
D28:24	N/A	Reserved	N/A	Not valid in DMA mode.
D23	R/W	ACK9	0	Generate an interrupt when ACK9 in FIFO Interrupt Status 2 register is asserted.
D22	R/W	NACK9	0	Generate an interrupt when NACK9 in FIFO Interrupt Status 2 register is asserted.
D21	R/W	ERROR9	0	Generate an interrupt when ERROR9 in FIFO Interrupt Status 2 register is asserted.
D20:16	N/A	Reserved	N/A	Not valid in DMA mode.
D15	R/W	ACK8	0	Generate an interrupt when ACK8 in FIFO Interrupt Status 2 register is asserted.
D14	R/W	NACK8	0	Generate an interrupt when NACK8 in FIFO Interrupt Status 2 register is asserted.
D13	R/W	ERROR8	0	Generate an interrupt when ERROR8 in FIFO Interrupt Status 2 register is asserted.
D12:08	N/A	Reserved	N/A	Not valid in DMA mode.

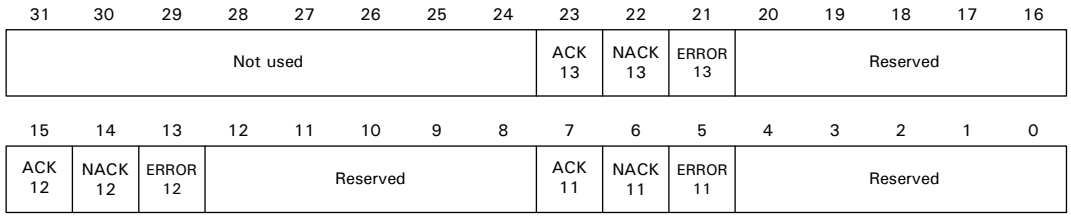
Table 476: FIFO Interrupt Enable 2 register

Bits	Access	Mnemonic	Reset	Description
D07	R/W	ACK7	0	Generate an interrupt when ACK7 in FIFO Interrupt Status 2 register is asserted.
D06	R/W	NACK7	0	Generate an interrupt when NACK7 in FIFO Interrupt Status 2 register is asserted.
D05	R/W	ERROR7	0	Generate an interrupt when ERROR7 in FIFO Interrupt Status 2 register is asserted.
D04:00	N/A	Reserved	N/A	Not valid in DMA mode.

Table 476: FIFO Interrupt Enable 2 register

FIFO Interrupt Enable 3 register

Address: 9010 3034



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:24	N/A	Not used	0x00	Always read as 0x00.
D23	R/W	ACK13	0	Generate an interrupt when ACK13 in FIFO Interrupt Status 3 register is asserted.
D22	R/W	NACK13	0	Generate an interrupt when NACK13 in FIFO Interrupt Status 3 register is asserted.
D21	R/W	ERROR13	0	Generate an interrupt when ERROR13 in FIFO Interrupt Status 3 register is asserted.
D20:16	N/A	Reserved	N/A	Not valid in DMA mode.
D15	R/W	ACK12	0	Generate an interrupt when ACK12 in FIFO Interrupt Status 3 register is asserted.

Table 477: FIFO Interrupt Enable 3 register

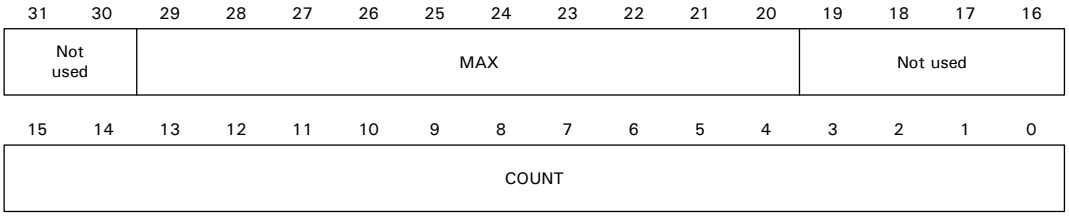
Bits	Access	Mnemonic	Reset	Description
D14	R/W	NACK12	0	Generate an interrupt when NACK12 in FIFO Interrupt Status 3 register is asserted.
D13	R/W	ERROR12	0	Generate an interrupt when ERROR12 in FIFO Interrupt Status 3 register is asserted.
D12:08	N/A	Reserved	N/A	Not valid in DMA mode.
D07	R/W	ACK11	0	Generate an interrupt when ACK11 in FIFO Interrupt Status 3 register is asserted,
D06	R/W	NACK11	0	Generate an interrupt when NACK11 in FIFO Interrupt Status 3 register is asserted.
D05	R/W	ERROR11	0	Generate an interrupt when ERROR11 in FIFO Interrupt Status 3 register is asserted.
D04:00	N/A	Reserved	N/A	Not valid in DMA mode.

Table 477: FIFO Interrupt Enable 3 register

FIFO Packet Control registers

Address: 9010 3080 / 3084 / 3088 / 308C / 3090 / 3094 / 3098 / 309C / 30A0 / 30A4 / 30A8 / 30AC / 30B0

The FIFO Packet Control registers contain packet information for the device block FIFOs. There are 13 of these registers in the USB module, one for each non-control endpoint and the two required for the bidirectional control endpoint.



Register bit assignment

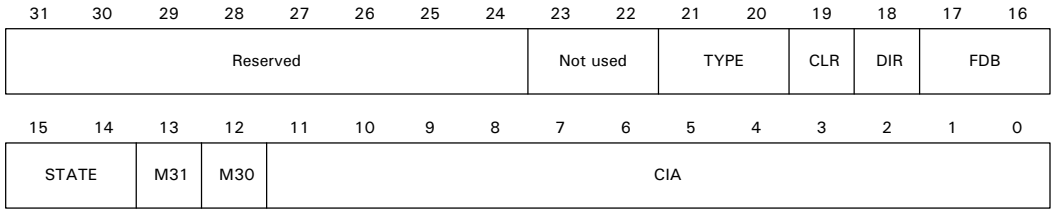
Bits	Access	Mnemonic	Reset	Description
D31:30	N/A	Not used	0x0	Always read as 0x0.
D29:20	R/W	MAX	0x040	Indicates the maximum packet size supported by the associated USB device endpoint. This value should be set to the same value as the maximum packet size (see page 783) in the Endpoint Descriptor register. **Note:** This field does not apply for FIFO #2 as that FIFO is dedicated to the IN direction of the control endpoint.
D19:16	N/A	Not used	0x00	Always read as 0x00.
D15:00	R	COUNT	0x0000	Indicates the number of error-free packets sent by the USB device module (USB-IN transactions) with the current DMA buffer descriptor for the associated FIFO. **Note:** This field does not apply for FIFO #1 as that FIFO is dedicated to the OUT direction of the control endpoint.

Table 478: FIFO Packet Control registers

FIFO Status and Control registers

Address: 9010 3100 / 3108 / 3110 / 3118 / 3120 / 3128 / 3130 / 3138 / 3140 / 3148 / 3150 / 3158 / 3160

The FIFO Status and Control registers contain additional status and control information for the device block FIFOs. There are 13 of these registers in the USB module, one for each non-control endpoint and the two required for the bidirectional endpoint.



Register bit assignment

Bits	Access	Mnemonic	Reset	Description
D31:24	N/A	Reserved	N/A	N/A
D23:22	R/W	Not used	0x0	Always write as 00.
D21:20	R/W	TYPE	0x0	**Type field** Defines the endpoint type associated with the FIFO. 00 Control 01 Isochronous 10 Bulk 11 Interrupt
D19	R/W	CLR	1	**Clear field** Writing a 1 places the FIFO into the reset state, disabling the associated endpoint. Any data currently in the FIFO is flushed. When the endpoint is configured for the IN direction and the type is either bulk or interrupt, this bit is also set to 1 by the hardware when a packet error is found by the host.
D18	R/W	DIR	0	**Direction field** 0 Defines the OUT direction 1 Defines the IN direction Defines the FIFO (endpoint) direction.
D17:16	R	FDB	0x0	**Valid data bytes** Indicates the valid number of bytes in the FIFO when receiving; this field is always 0 when transmitting. **Note:** This field is not used when using the DMA controller.

Table 479: FIFO Status and Control registers

Bits	Access	Mnemonic	Reset	Description
D15:14	R	STATE	0x0	**State field** Defines the state of the endpoint after the most recent communication with the USB device module. 00 Undefined 01 Data phase transaction 10 Status phase transaction 11 No-data status phase transaction This field is used primarily for diagnostic purposes.
D13	R	M31	0	**Successful transfer status bit** 0 Unsuccessful transfer 1 Successful transfer **For successful transfers** ■ For IN packets: If the host sends an ACK handshake (when the command involves a handshake), this bit is set, indicating that the data is transferred successfully to the host. ■ For OUT and SETUP packets: When set, this bit also indicates that an ACK handshake is being sent to the host. **For unsuccessful transfers** ■ For OUT packets with errors, this bit is cleared. ■ For IN packets, this bit is cleared if an ACK handshake was not sent. ■ When cleared for IN and OUT packets, this bit also indicates a timeout or NAK/STALL handshake is being sent to the host.
D12	R	M30	0	**Setup command status bit** 0 Current transaction is not a setup command 1 Current transaction is a setup command

Table 479: FIFO Status and Control registers

Bits	Access	Mnemonic	Reset	Description
D11:00	R	CIA	0x000	**Configuration Interface Alternate** Value depends on setting of the M30 field (D12 in this register). ■ If M30 = 1, this field contains the value 0x100. ■ If the M30 = 0, this field contains the following: [11:08] — configuration [07:04] — interface [03:00] — alternate

Table 479: FIFO Status and Control registers

Timing

CHAPTER 17

This chapter provides the electrical specifications, or timing, integral to the operation of the NS9775. Timing includes information about DC and AC characteristics, output rise and fall timing, and crystal oscillator specifications.

Electrical characteristics

The NS9775 operates at a 1.5V core, with 3.3V I/O ring voltages.

Absolute maximum ratings

Permanent device damage can occur if the absolute maximum ratings are exceeded for even an instant.

Parameter	Symbol†	Rating	Unit
DC supply voltage	V_{DDA}	-0.3 to +3.9	V
DC input voltage	V_{INA}	-0.3 to V_{DDA} +0.3	V
DC output voltage	V_{OUTA}	-0.3 to V_{DDA} +0.3	V
DC input current	I_{IN}	±10	mA
Storage temperature	T_{STG}	-40 to +125	°C
† V_{DDA}, V_{INA}, V_{OUTA}: Ratings of I/O cells for 3.3V interface			

Table 480: Absolute maximum ratings

Recommended operating conditions

Recommended operating conditions specify voltage and temperature ranges over which a circuit's correct logic function is guaranteed. The specified DC electrical characteristics are satisfied over these ranges.

Parameter	Symbol†	Rating	Unit
DC supply voltage	V_{DDA}	3.0 to 3.6	V
	V_{DDC} (core)	1.4 to 1.6	V
	V_{DDC} (PLL)	1.425 to 1.575	V
Maximum junction temperature	T_J	125	°C
† V_{DDA}: Ratings of I/O cells for 3.3V interface V_{DDC}: Ratings of internal cells			

Table 481: Recommended operating conditions

Maximum power dissipation

Table 482 shows the maximum power dissipation, including sleep mode information, for I/O and core.

Operation				Sleep mode with wake up on			
CPU clock	Full	No PCI	No PCI, LCD	All ports	BBus ports	AHB bus ports	No wake up ports
Total@ 200 MHZ	1.7W	1.55 W	1.5 W	350 mW	285 mW	240 mW	180 mW
Core	1.05 W	1 W	1 W	260 mW	210 mW	220 mW	170 mW
I/O	0.65 W	0.55 W	0.5 W	90 mW	75 mW	20 mW	10 mW

Table 482: NS9775 power dissipation

Typical power dissipation

The next table shows typical power dissipation for I/O and core.

Operation				
CPU clock		Full	No PCI	No PCI, LCD
Total@ 200 MHZ		952 mW	886 mW	809 mW
	Core	419 mW	353 mW	287 mW
	I/O	533 mW	533 mW	522 mW

DC electrical characteristics

DC characteristics specify the worst-case DC electrical performance of the I/O buffers that are guaranteed over the specified temperature range.

Inputs

All electrical inputs are 3.3V interface.

Note: V_{SS} = 0V (GND)

Sym	Parameter	Condition	Value		Unit
V_{IH}	High-level input voltage:		Min		
	LVTTL level			2.0	V
	PCI level			$0.5V_{DDA}$	V
V_{IL}	Low-level input voltage:		Max		
	LVTTL level			0.8	V
	PCI level			$0.3V_{DDA}$	V
I_{IH}	High level input current (no pulldown)	$V_{INA} = V_{DDA}$	Min/Max	-10/10	µA
	Input buffer with pulldown		Min/Max	10/200	µA
I_{IL}	Low-level input current (no pullup	$V_{INA} = V_{SS}$	Min/Max	-10/10	µA
	Input buffer with pullup		Min/Max	10/200	µA
I_{OZ}	High-impedance leakage current	$V_{OUTA} = V_{DDA}$ or V_{SS}	Min/Max	-10/10	µA
I_{DDS}	Quiescent supply current	$V_{INA} = V_{DDA}$ or V_{SS}	Max	TBD	

Table 483: DC electrical inputs

USB DC electrical inputs

Symbol	Parameter	Min	Max	Units	Notes
V_{IH}	Input high level (driven)	2.0	V_{DDA}-0.6	V	
V_{IZ}	Input high level (floating)	2.7	3.6	V	

Table 484: USB DC electrical inputs

Symbol	Parameter	Min	Max	Units	Notes
V_{IL}	Input low level		0.8	V	
V_{DI}	Differential input sensitivity	0.2		V	1
V_{CM}	Differential common mode range	0.8	2.5	V	2

Table 484: USB DC electrical inputs

Notes:

1 |(usb_dp) – (usb_dm)|

2 Includes V_{DI} range.

Outputs

All electrical outputs are 3.3V interface.

Sym	Parameter	Value		Unit
V_{OH}	High-level output voltage (LVTTL)	Min	V_{DDA}-0.6	V
V_{OL}	Low-level output voltage (LVTTL)	Max	0.4	V
V_{OH}	PCI high-level output voltage	Min	$0.9V_{DDA}$	V
V_{OL}	PCI low-level output voltage	Max	$0.1V_{DDA}$	V

Table 485: DC electrical outputs

USB DC electrical outputs

Symbol	Parameter	Min	Max	Units	Notes
V_{OL}	Output low level	0.0	0.3	V	1
V_{OH}	Output high level	2.8	3.6	V	2
V_{CRS}	Output signal crossover voltage	1.3	2.0	V	3

Table 486: USB DC electrical outputs

Notes:

1 Measured with R_L of 1.425k ohm to 3.6V.

2 Measured with R_L of 14.25k ohm to GND.

3 Excluding the first transition from the idle state.

Power sequencing

Use these requirements for power sequencing:

- 3.3 volt and 1.5 volt power must be applied to the NS9775 ASIC simultaneously, but never more than 100 milliseconds difference.
- The ASIC NS9775 3.3 volt/1.5 volt supplies must maintain a relationship to the power supplies for the external board circuits such that ASIC I/O input voltage does not exceed ±0.3V before the ASIC power supplies are applied.
- 3.3 and 1.5 volt power should never be cycled more than 100 times per day.

Memory timing

Note: All AC characteristics are measured with 35pF, unless otherwise noted.

Memory timing contains parameters and diagrams for both SDRAM and SRAM timing.

Table 487 describes the values shown in the SDRAM timing diagrams (Figure 107 through Figure 115).

Parm	Description	Min	Max	Unit	Notes
M1	data input setup time to rising	1.6		ns	
M2	data input hold time to rising	3.3		ns	
M3	clk_out high to clk_en high		6.1	ns	
M4	clk_out high to address valid		6.1	ns	
M5	clk_out high to data_mask		6.1	ns	1, 2
M6	clk_out high to dy_cs_n low		6.1	ns	3, 4
M7	clk_out high to ras_n low		6.1	ns	
M8	clk_out high to cas_n low		6.1	ns	
M9	clk_out high to we_n low		6.1	ns	
M10	clk_out high to data out		6.2	ns	
M11	address hold time	3.5			
M12	data out hold time	3.8			
M13	clk_en high to sdram access	2	2	clock	
M14	end sdram access to clk_en low	2	2	clock	

Table 487: SDRAM timing parameters

Notes:

1 All four data_mask signals are used for all transfers.

2 All four data_mask signals will go low during a read cycle, for both 16-bit and 32-bit transfers.

3 Only one of the four `clk_out` signals is used.

4 Only one of the four `dy_cs_n` signals is used.

SDRAM burst read (16-bit)

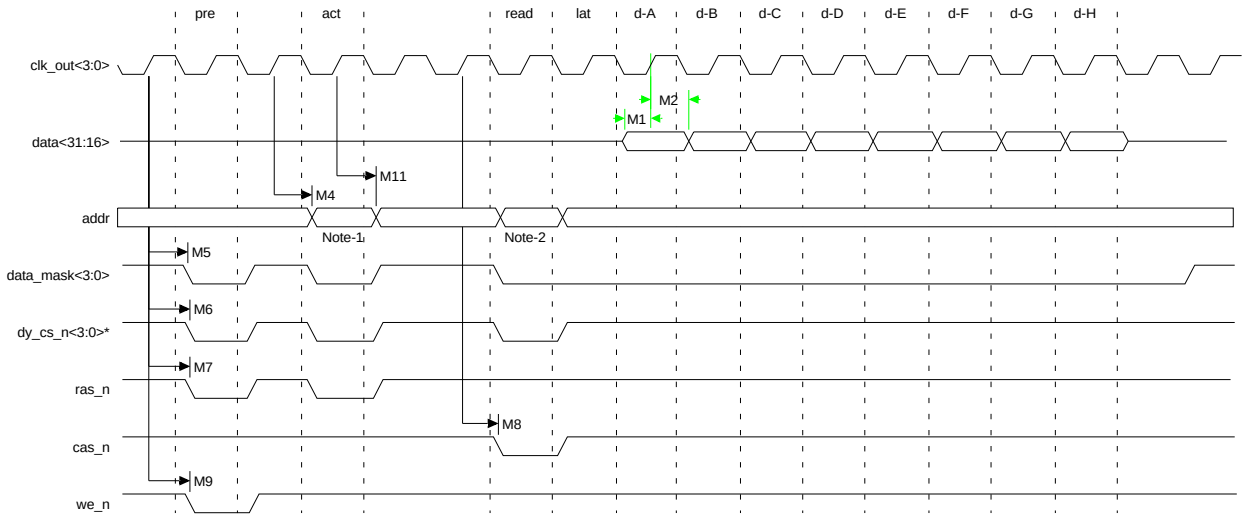


Figure 107: SDRAM burst read (16-bit) timing

Notes:

1 This is the bank and RAS address.

2 This is the CAS address.

SDRAM burst read (16-bit), CAS latency = 3

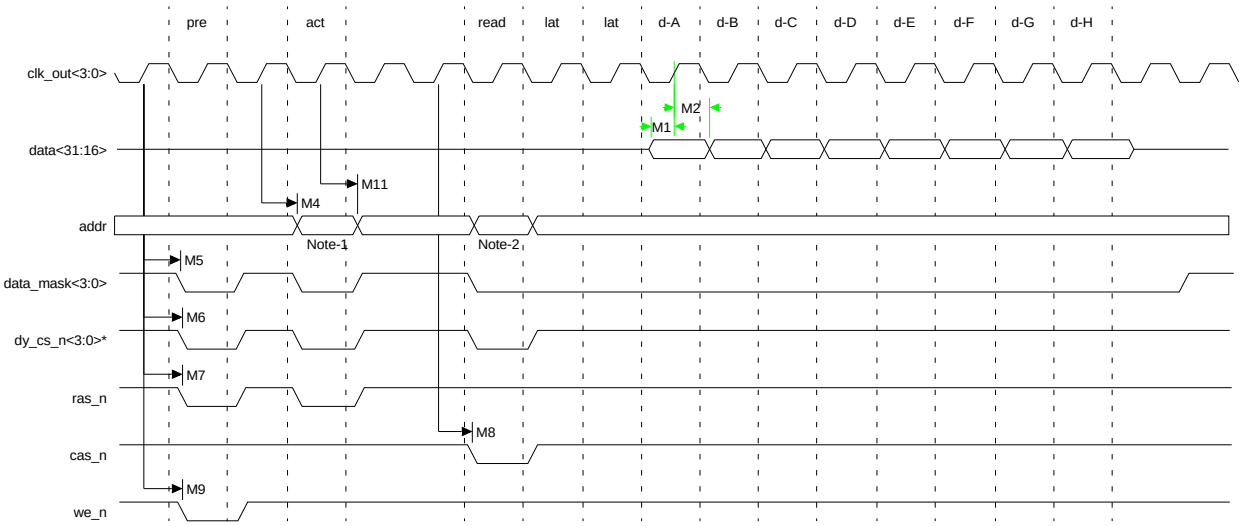


Figure 108: SDRAM burst read (16-bit), CAS latency = 3 timing

Notes:

1 This is the bank and RAS address.

2 This is the CAS address.

SDRAM burst write (16-bit)

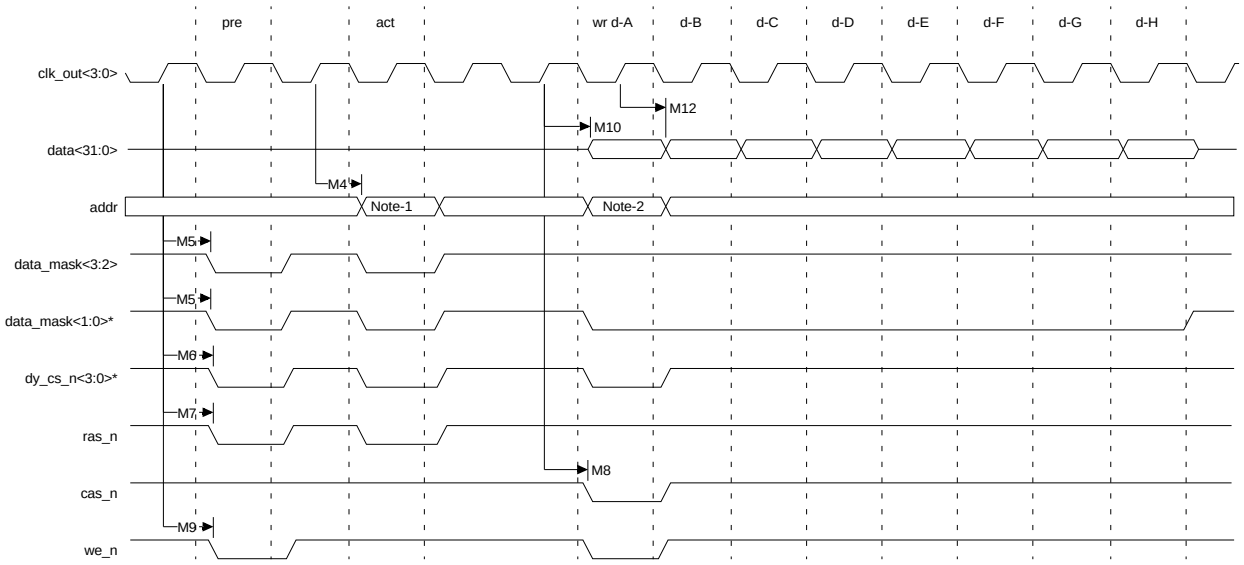


Figure 109: SDRAM burst write (16-bit) timing

Notes:

1 This is the bank and RAS address.

2 This is the CAS address.

SDRAM burst read (32-bit)

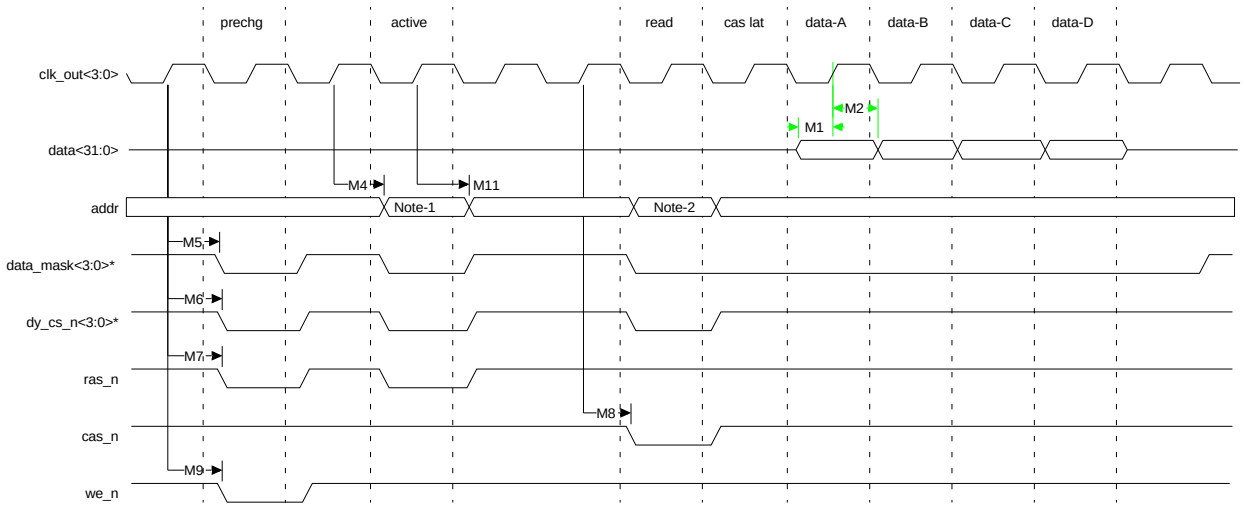


Figure 110: SDRAM burst read (32-bit) timing

Notes:

1 This is the bank and RAS address.

2 This is the CAS address.

SDRAM burst read (32-bit), CAS latency = 3

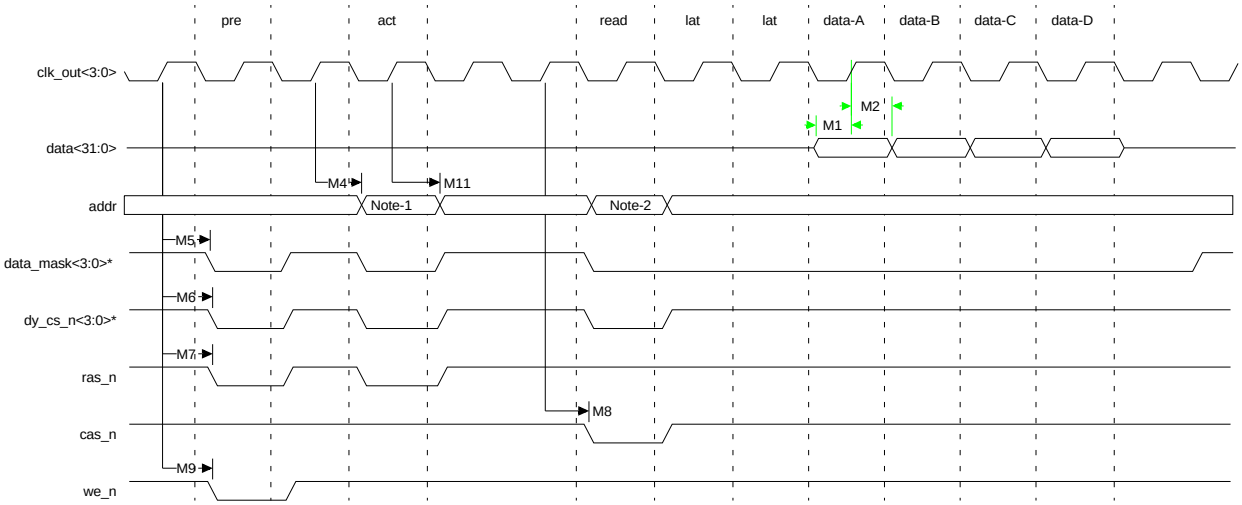


Figure 111: SDRAM burst read (32-bit), CAS latency = 3 timing

Notes:

1 This is the bank and RAS address.

2 This is the CAS address.

SDRAM burst write (32-bit)

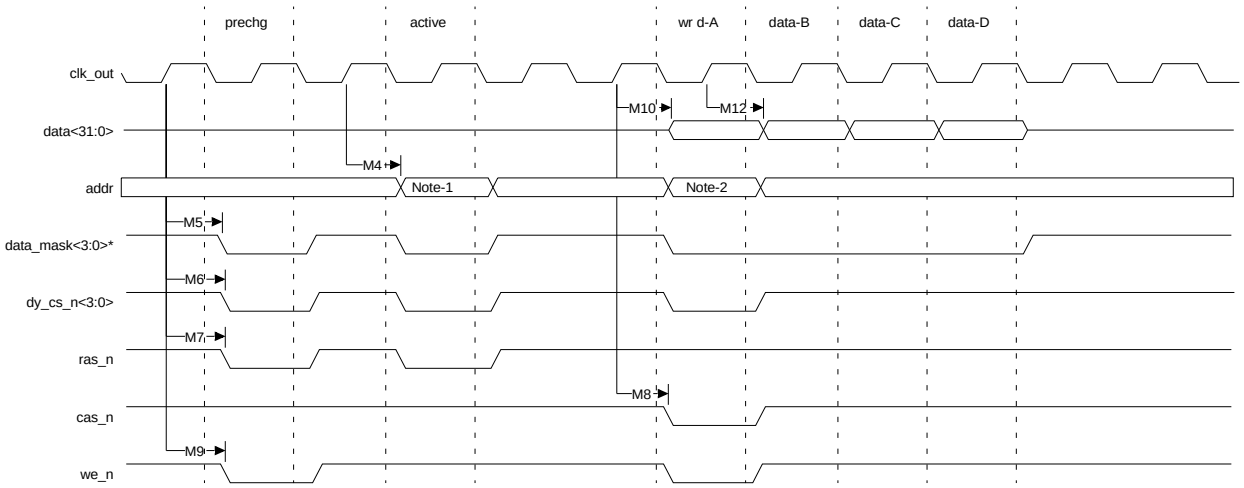


Figure 112: SDRAM burst write (32-bit) timing

Notes:

1 This is the bank and RAS address.

2 This is the CAS address.

SDRAM load mode

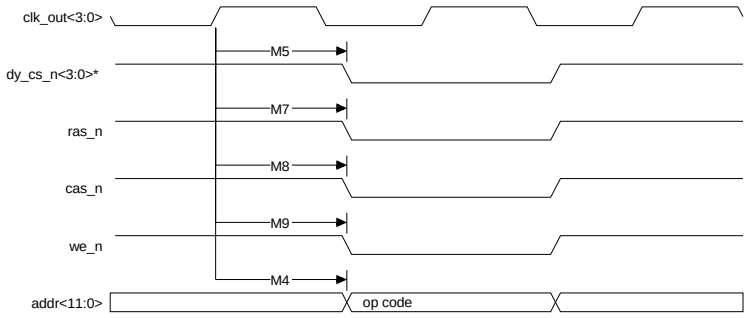


Figure 113: SDRAM load mode timing

SDRAM refresh mode

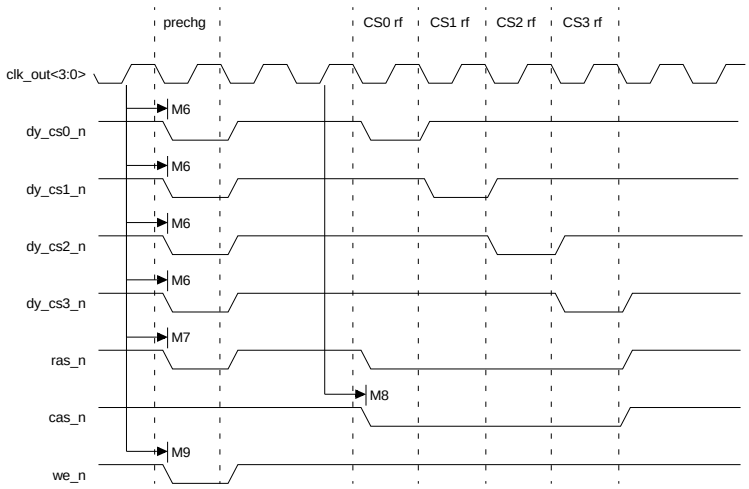


Figure 114: SDRAM refresh mode timing

Clock enable timing

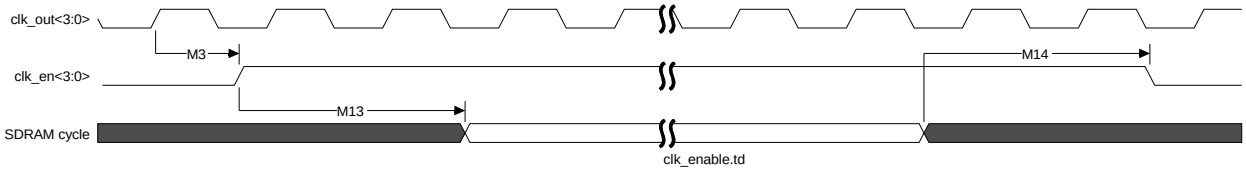


Figure 115: Clock enable timing

Table 488 describes the values shown in the SRAM timing diagrams (Figure 116 through Figure 121).

Parm	Description	Min	Max	Unit	Notes
M15	clock high to data out valid	-2	+2	ns	
M16	data out hold time from clock high	-2	+2	ns	
M17	clock high to address valid	-2	+2	ns	
M18	address hold time from clock high	-2	+2	ns	
M19	clock high to st_cs_n low	-2	+2	ns	2
M20	clock high to st_cs_n high	-2	+2	ns	2
M21	clock high to we_n low	-2	+2	ns	
M22	clock high to we_n high	-2	+2	ns	
M23	clock high to byte_lanes low	-2	+2	ns	
M24	clock high to byte_lanes high	-2	+2	ns	
M25	data input setup time to rising clk	10		ns	
M26	data input hold time to rising clk	0		ns	
M27	clock high to oe_n low	-2	+2	ns	
M28	clock high to oe_n high	-2	+2	ns	

Table 488: SRAM timing parameters

Notes:

1 The (CPU clock out / 2) signal is for reference only.

2 Only one of the four dy_cs_n signals is used. The diagrams show the active low configuration, which can be reversed (active high) with the PC field.

3 Use this formula to calculate the length of the st_cs_n signal:

Tacc + board delay + (optional buffer delays, both address out and data in) + 10ns

Static RAM read cycles with 0 wait states

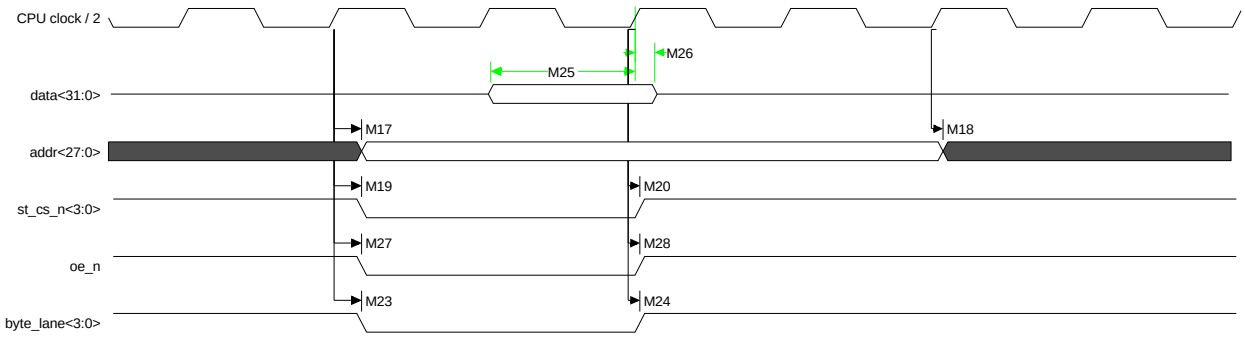


Figure 116: Static RAM read cycles with 0 wait states timing

- WTRD = 1

  WOEN = 1
- If the PB field is set to 1, all four `byte_lane` signals will go low for 32-bit, 16-bit, and 8-bit read cycles.
- If the PB field is set to 0, the `byte_lane` signal will always be high.

Static RAM asynchronous page mode read, WTPG = 1

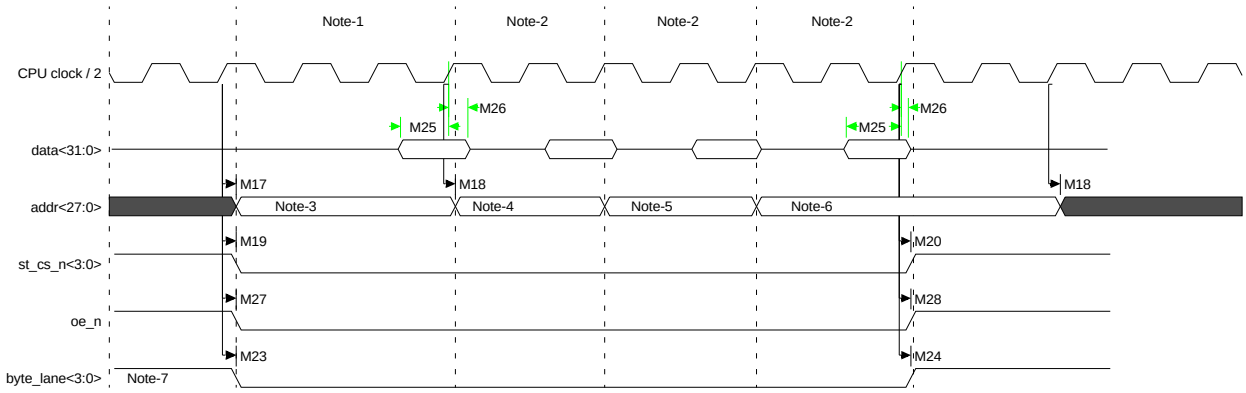


Figure 117: Static RAM asynchronous page mode read, WTPG = 1 timing

- WTPG = 1

  WTRD = 2
- If the PB field is set to 1, all four `byte_lane` signals will go low for 32-bit, 16-bit, and 8-bit read cycles.
- The asynchronous page mode will read 16 bytes in a page cycle. A 32-bit bus will do four 32-bit reads, as shown (3-2-2-2). A 16-bit bus will do eight 16-bit reads (3-2-2-2-3-2-2-2) per page cycle, and an 8-bit bus will do sixteen 8-bit reads (3-2-2-2-3-2-2-2-3-2-2-2-3-2-2-2) per page cycle. 3-2-2-2 is the example used here, but the WTRD and WTPG fields can set them differently.

Notes:

1 The length of the first cycle in the page is determined by the WTRD field.

2 The length of the 2nd, 3rd, and 4th cycles is determined by the WTPG field.

3 This is the starting address. The least significant two bits will always be '00.'

4 The least significant two bits in the second cycle will always be '01.'

5 The least significant two bits in the third cycle will always be '10.'

6 The least significant two bits in the fourth cycle will always be '11.'

7 If the PB field is set to 0, the `byte_lane` signal will always be high during a read cycle.

Static RAM read cycle with configurable wait states

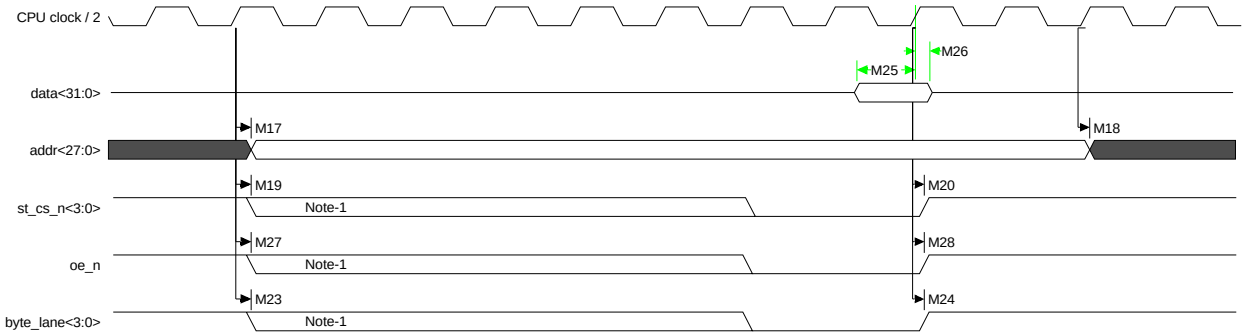


Figure 118: Static RAM read cycle with configurable wait states

- WTRD = from 1 to 15

  WOEN = from 0 to 15
- If the PB field is set to 1, all four `byte_lane` signals will go low for 32-bit, 16-bit, and 8-bit read cycles.
- If the PB field is set to 0, the `byte_lane` signal will always be high.

Static RAM sequential write cycles

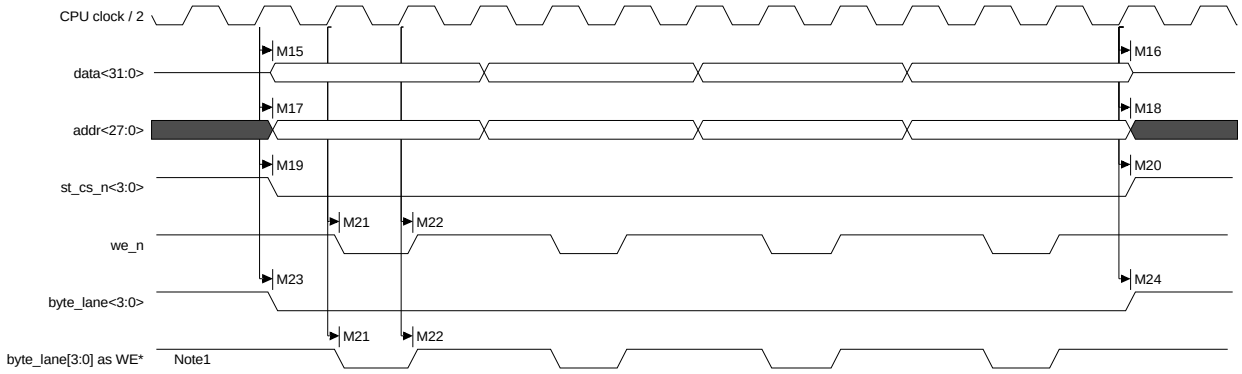


Figure 119: Static RAM sequential write cycles

- WTWR = 0
  WWEN = 0
- During a 32-bit transfer, all four `byte_lane` signals will go low.
- During a 16-bit transfer, two `byte_lane` signals will go low.
- During an 8-bit transfer, only one `byte_lane` signal will go low.

Note:

1 If the PB field is set to 0, the `byte_lane` signals will function as write enable signals and the `we_n` signal will always be high.

Static RAM write cycle

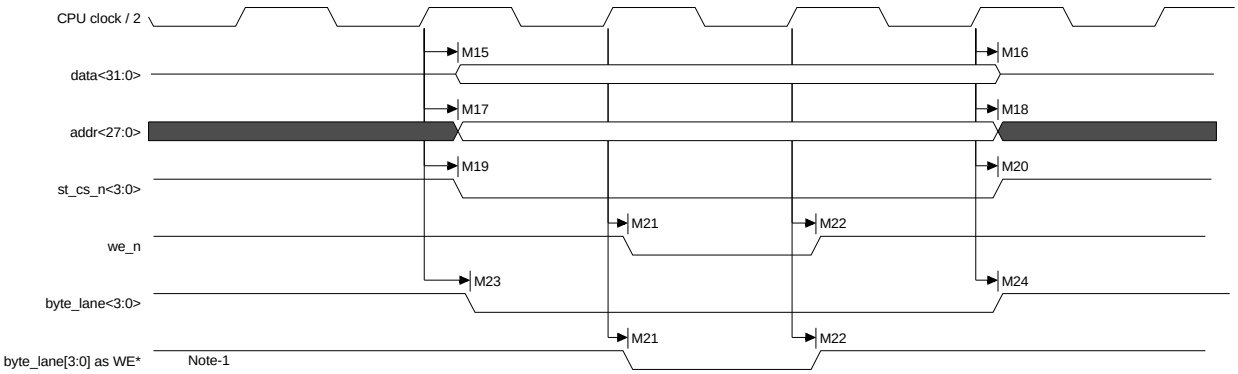


Figure 120: Static RAM write cycle

- WTWR = 0
  WWEN = 0
- During a 32-bit transfer, all four `byte_lane` signals will go low.
- During a 16-bit transfer, two `byte_lane` signals will go low.
- During an 8-bit transfer, only one `byte_lane` signal will go low.

Note:

1 If the PB field is set to 0, the `byte_lane` signals will function as write enable signals and the `we_n` signal will always be high.

Static write cycle with configurable wait states

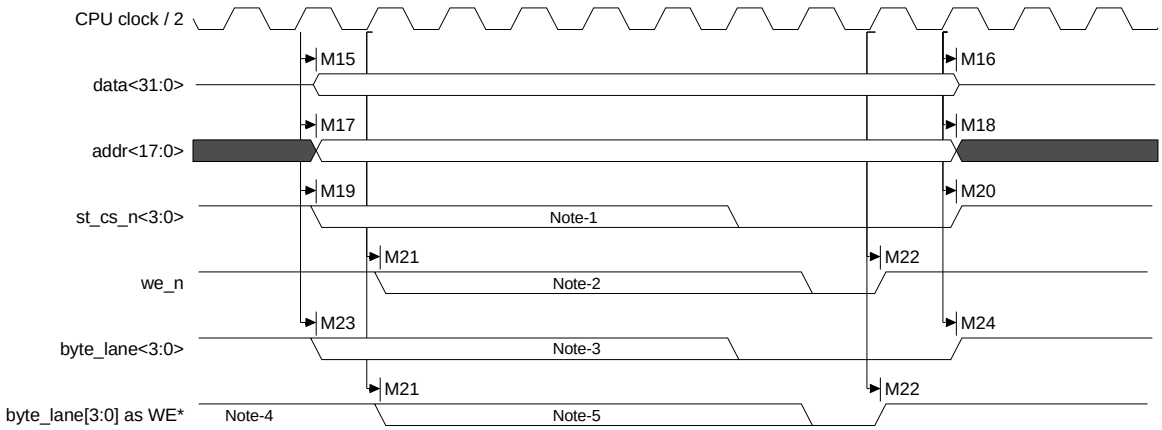


Figure 121: Static write cycle with configurable wait states

- WTWR = from 0 to 15
  WWEN = from 0 to 15
- The WTWR field determines the length on the write cycle.
- During a 32-bit transfer, all four `byte_lane` signals will go low.
- During a 16-bit transfer, two `byte_lane` signals will go low.
- During an 8-bit transfer, only one `byte_lane` signal will go low.

Notes:

1 Timing of the `st_cs_n` signal is determined with a combination of the WTWR and WWEN fields. The `st_cs_n` signal will always go low at least one clock before `we_n` goes low, and will go high one clock after `we_n` goes high.

2 Timing of the `we_n` signal is determined with a combination of the WTWR and WWEN fields.

3 Timing of the `byte_lane` signals is determined with a combination of the WTWR and WWEN fields. The `byte_lane` signals will always go low one clock before `we_n` goes low, and will go one clock high after `we_n` goes high.

4 If the PB field is set to 0, the `byte_lane` signals will function as the write enable signals and the `we_n` signal will always be high.

5 If the PB field is set to 0, the timing for the `byte_lane` signals is set with the WTWR and WWEN fields.

Ethernet timing

Note: All AC characteristics are measured with 10pF, unless otherwise noted.

Table 489 describes the values shown in the Ethernet timing diagrams (Figure 122 and Figure 123).

Parameter	Description	Min	Max	Unit	Notes
E1	MII tx_clk to txd, tx_en, tx_er	3	11	ns	2
E2	MII rxd, rx_en, rx_er setup to rx_clk rising	3		ns	
E3	MII rxd, rx_en, rx_er hold from rx_clk rising	1		ns	
E4	mdio (input) setup to mdc rising	10		ns	
E5	mdio (input) hold from mdc rising	0		ns	
E6	mdc to mdio (output)	18	38	ns	1,2
E7	mdc period	80		ns	
E8	RMII ref_clk to txd, tx_en	3	12	ns	2
E9	RMII rxd, crs, rx_er setup to ref_clk rising	3		ns	
E10	RMII rxd, crs, rx_er hold from ref_clk rising	1		ns	
E11	MII rx_clk to cam_req	3	10	ns	
E12	MII cam_reject setup to rx_clk rising	N/A		ns	3
E13	MII cam_reject hold from rx_clk rising	N/A		ns	3

Table 489: Ethernet timing characteristics

Notes:

1 Minimum specification is for fastest AHB bus clock of 100 MHz. Maximum specification is for slowest AHB bus clock of 50 MHz.

2 C_{load} = 10pf for all outputs and bidirects.

3 No setup and hold requirements for `cam_reject` because it is an asynchronous input. This is also true for RMII PHY applications.

Ethernet MII timing

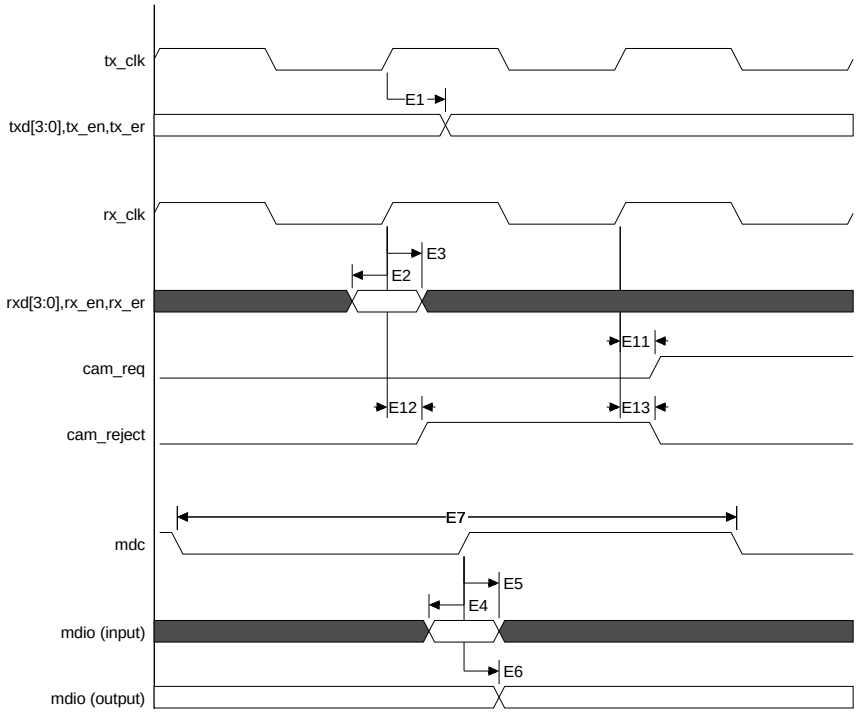


Figure 122: Ethernet MII timing

Ethernet RMII timing

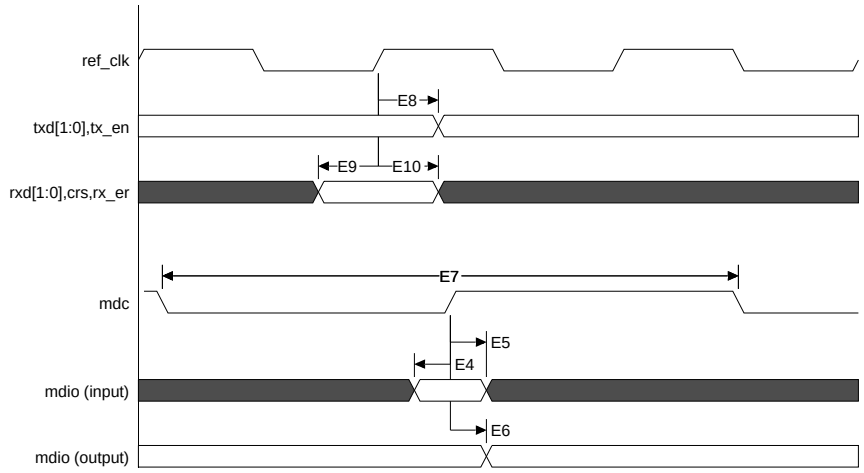


Figure 123: Ethernet RMII timing

PCI timing

Note: All AC characteristics are measured with 10pF, unless otherwise noted.

Table 490 and Table 491 describe the values shown in the PCI timing diagrams (Figure 124 through Figure 130).

Parameter	Description	Min	Max	Units	Notes
P1	pci_clk_in to signal valid delay	2	9	ns	1,2
P2	Input setup to pci_clk_in	5		ns	1
P3	Input hold from pci_clk_in	0		ns	
P4	pci_clk_in to signal active	2		ns	2
P5	pci_clk_in to signal float		28	ns	2
P6	pci_clk_out high time	50%-1	50%+1	ns	3
P7	pci_clk_out low time	50%-1	50%+1	ns	3
P8	pci_clk_in cycle time	30		ns	
P9	pci_clk_in high time	11		ns	
P10	pci_clk_in low time	11		ns	

Table 490: PCI timing characteristics

Notes:

1 Parameters same for bussed and point-to-point signals.

2 CLOAD = 10pf on all outputs

3 `pci_clk_out` high and low times specified as 50% of the clock period +/-1 ns.

Parameter	Description	Min	Max	Units	Notes
P1	pci_clk_in to signal valid delay	2	10	ns	1
P2	Input setup to pci_clk_in	5		ns	1
P3	Input hold from pci_clk_in	0		ns	
P4	pci_clk_in to signal active	2		ns	1
P5	pci_clk_in to signal float		28	ns	1
P6	pci_clk_out high time	50%-1	50%+1	ns	2
P7	pci_clk_out low time	50%-1	50%+1	ns	2
P8	pci_clk_in cycle time	30		ns	
P9	pci_clk_in high time	11		ns	
P10	pci_clk_in low time	11		ns	

Table 491: CardBus timing characteristics

Notes:

1 Minimum times are specified with 0pf and maximum times are specified with 30pf.

2 `pci_clk_out` high and low times specified as 50% of the clock period +/-1 ns.

Internal PCI arbiter timing

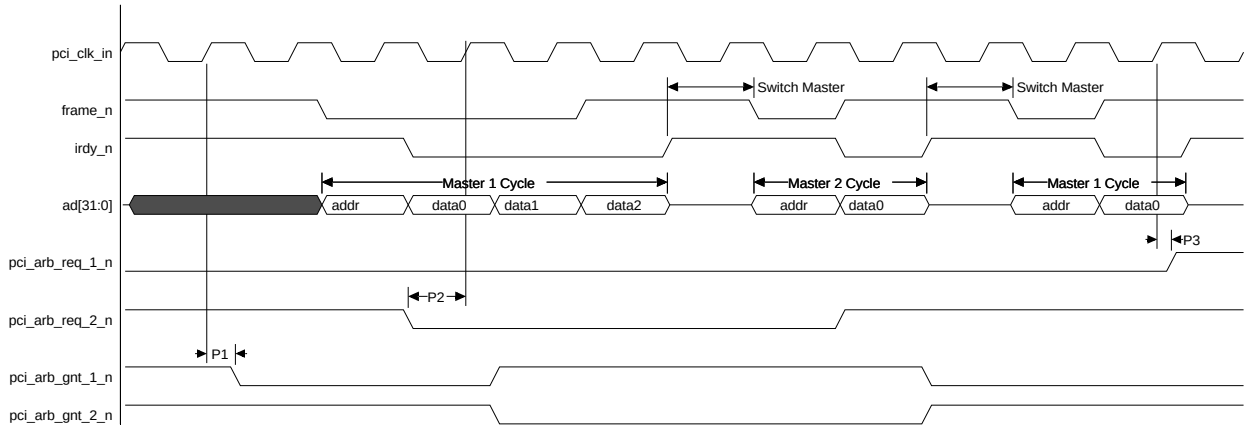


Figure 124: Internal PCI arbiter timing

PCI burst write from NS9775 timing

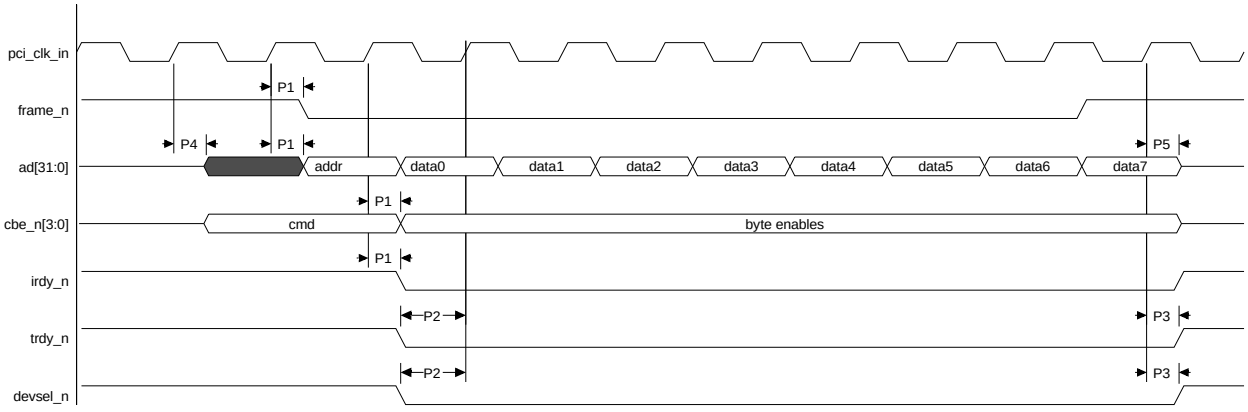


Figure 125: PCI burst write from NS9775 timing

Note: The functional timing for `trdy_n` and `devsel_n` shows the fastest possible response from the target.

PCI burst read from NS9775 timing

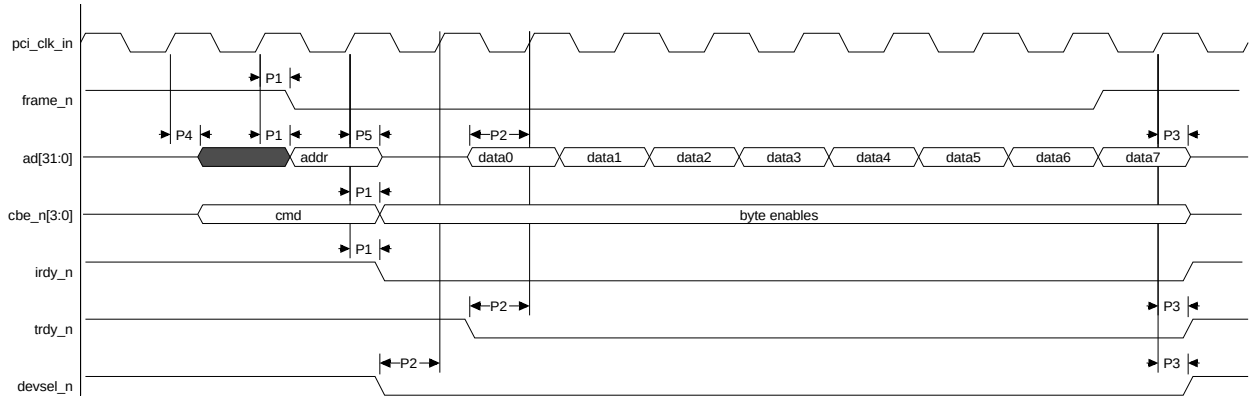


Figure 126: PCI burst read from NS9775 timing

Note: The functional timing for `trdy_n`, `devsel_n`, and the read data on `ad[31:0]` shows the fastest possible response from the target.

PCI burst write to NS9775 timing

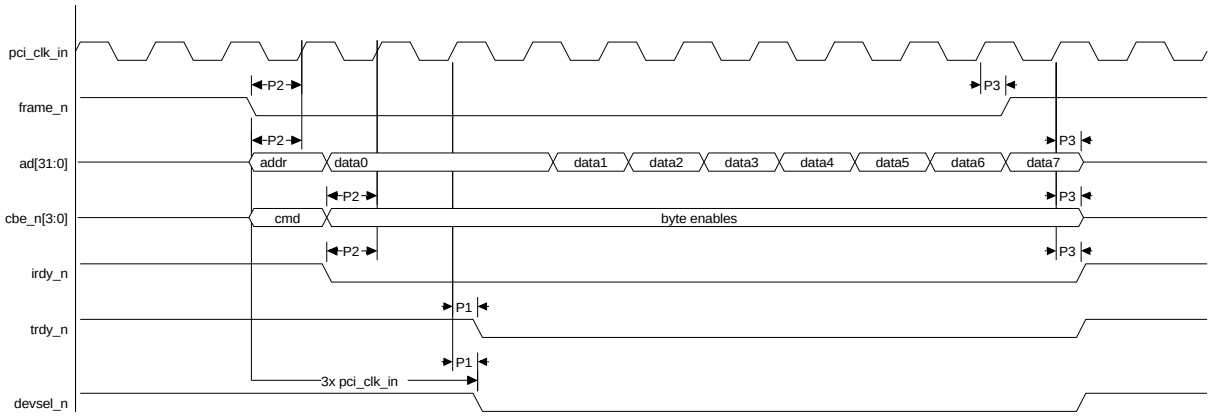


Figure 127: PCI burst write to NS9775 timing

PCI burst read to NS9775 timing

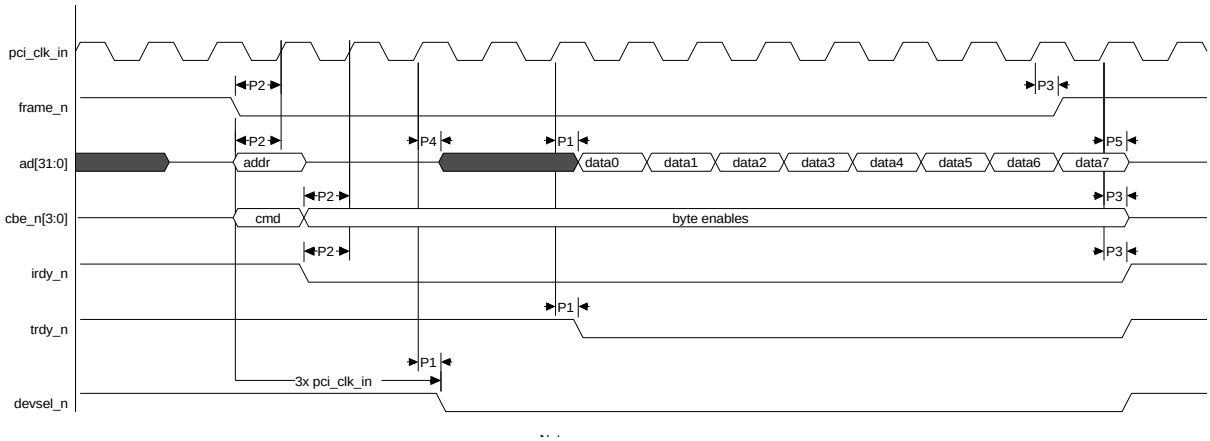


Figure 128: PCI burst read to NS9775 timing

Note: The functional timing for valid read data on `ad[31:0]` is just an example. The actual response time will depend on when the PCI bridge gets access to the AHB bus internal to NS9775.

PCI clock timing

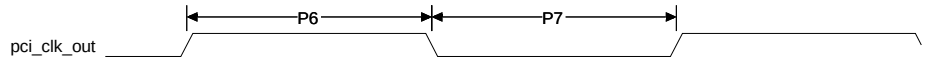


Figure 129: pci_clock_out timing

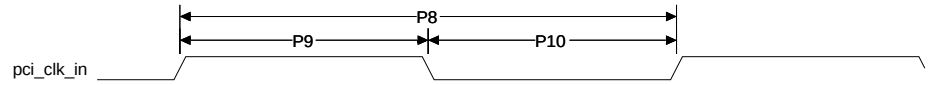


Figure 130: pci_clk_in timing

I²C timing

Note: All AC characteristics are measured with 10pF, unless otherwise noted.

Table 492 describes the values shown in the I²C timing diagram (Figure 131).

		Standard mode		Fast mode		
Parm	**Description**	**Min**	**Max**	**Min**	**Max**	**Unit**
C1	iic_sda to iic_scl START hold time	4.0		0.6		µs
C2	iic_scl low period	4.7		1.3		µs
C3	iic_scl high period	4.7		1.3		µs
C4	iic_scl to iic_sda DATA hold time	0		0		µs
C5	iic_sda to iic_scl DATA setup time	250		100		ns
C6	iic_scl to iic_sda START setup time	4.7		0.6		µs
C7	iic_scl to iic_sda STOP setup time	4.0		0.6		µs

Table 492: I²C timing parameters

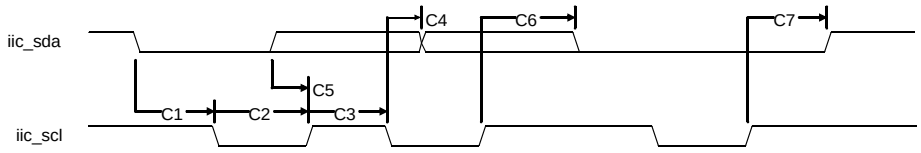


Figure 131: I²C timing

LCD timing

Note: All AC characteristics are measured with 10pF, unless otherwise noted.

Table 493 describes the values shown in the LCD timing diagrams (Figure 132 through Figure 138).

Parm	Description	Register	Value	Units
L1	Horizontal front porch blanking	LCDTiming0	HFP + 1	CLCP periods
L2	Horizontal sync width	LCDTiming0	HSW + 1	CLCP periods
L3	Horizontal period	N/A	L1 + L2 + L15 + L4	CLCP periods
L4	Horizontal backporch	LCDTiming0	HBP + 1	CLCP periods
L5	TFT active line	LCDTiming0	16*(PPL + 1) (see note 3)	CLCP periods
L6	LCD panel clock frequency	LCDTiming1	**For BCD = 0:** CLCDCLK/(PCD + 2) **For BCD = 1:** CLCDCLK (see note 1)	MHz
L7	TFT vertical sync width	LCDTiming1	VSW + 1	H lines
L8	TFT vertical lines/frame	N/A	L7 + L9 + L10 + L11	H lines
L9	TFT vertical back porch	LCDTiming1	VBP	H lines
L10	TFT vertical front porch	LCDTiming1	VFP	H lines
L11	Active lines/frame	LCDTiming1	LPP + 1	H lines
L12	STN HSYNC inactive to VSYNC active	LCDTiming0	HBP + 1	CLCP periods
L13	STN vertical sync width	N/A	1	H lines
L14	STN vertical lines/frame	N/A	L11 + L16	H lines
L15	STN active line	LCDTiming2	CPL + 1 (see note 4)	CLCP periods
L16	STN vertical blanking	LCDTiming1	VSW + VFP + VBP + 1	H lines
L17	STN CLCP inactive to HSYNC active	LCDTiming0	HFP + 1.5	CLCP periods

Table 493: LCD timing parameters

Parm	Description	Register	Value	Units
L18	CLCP to data/control (see notes 7 and 8)		-1.0 (min) +1.5 (max)	ns
L19	CLCP high (see notes 8, 9)		50% ±0.5ns	ns
L20	CLCP low (see notes 8, 9)		50% ±0.5ns	ns
L21	TFT VSYNC active to HSYNC active (see note 8)		-0.1ns (min) +0.1ns (max)	ns
L22	TFT VSYNC active to HSYNC inactive	LCDTiming0	HSW	CLCP periods
L23	STN VSYNC active to HSYNC inactive	LCDTiming0	**STN color:** 14+HSW+HFP **STN Mono8:** 6+HSW+HFP **STN Mono4:** 10+HSW+HFP	CLCP periods
L24	STN HSYNC inactive to VSYNC inactive	LCDTiming0	HBP+1	CLCP periods
L25	STN VSYNC inactive to HSYNC active	LCDTiming0	**STN color:** HFP+13 **STN Mono8:** HFP+15 **STN Mono4:** HFP+9	CLCP periods
L26	CLCP period		12.5ns (min)	ns

Table 493: LCD timing parameters

Notes:

1 CLCDCLK is selected from 5 possible sources:

— lcdclk/2 (lcdclk is an external oscillator)

— AHB clock

— AHB clock/2

— AHB clock/4

— AHB clock/8

See the LCD Controller chapter for acceptable clock frequencies for the different display configurations.

2 The polarity of CLLP, CLFP, CLCP, and CLAC can be inverted using control fields in the LCDTiming1 register.

3 The CPL field in the LCDTiming2 register must also be programmed to T5-1.

4 The PPL field in the LCDTiming0 register must also be programmed correctly.

5 These data widths are supported:
   — 4-bit mono STN single panel
   — 8-bit mono STN single panel
   — 8-bit color STN single panel
   — 4-bit mono STN dual panel (8 bits to LCD panel)
   — 8-bit mono STN dual panel (16 bits to LCD panel)
   — 8-bit color STN dual panel (16 bits to LCD panel)
   — 24-bit TFT
   — 18-bit TFT
6 See "LCDTiming0," beginning on page 591, and "LCDTiming1," beginning on page 594, for definitions of the bit fields referred to in this table.
7 Note that data is sampled by the LCD panel on the falling edge of the CLCP in Figure 138, "LCD output timing," on page 838). If the polarity of CLCP is inverted, this parameter is relative to CLCP falling, instead.
8 C_{load} = 10pf on all outputs.
9 CLCP high and low times specified as 50% of the clock period +/- 0.5ns.
10 Maximum allowable LCD panel clock frequency is 80 MHz.

Horizontal timing for STN displays

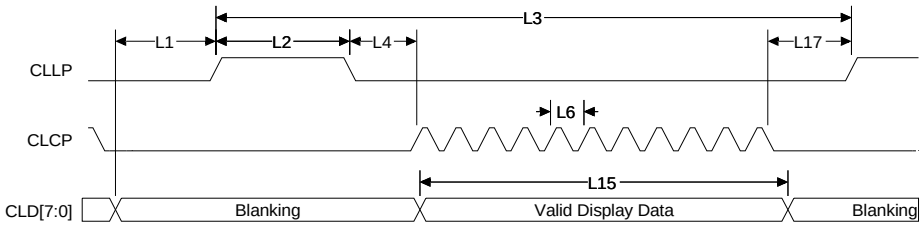


Figure 132: Horizontal timing for STN displays

Vertical timing for STN displays

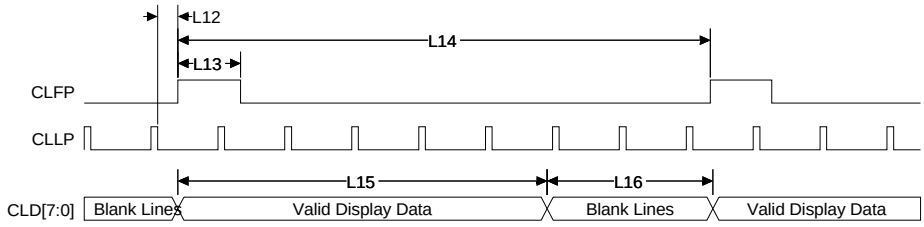


Figure 133: Vertical timing parameters for STN displays

Horizontal timing for TFT displays

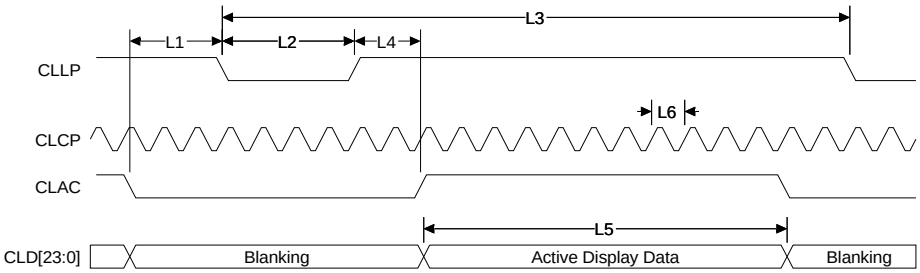


Figure 134: Horizontal timing parameters for TFT displays

Vertical timing for TFT displays

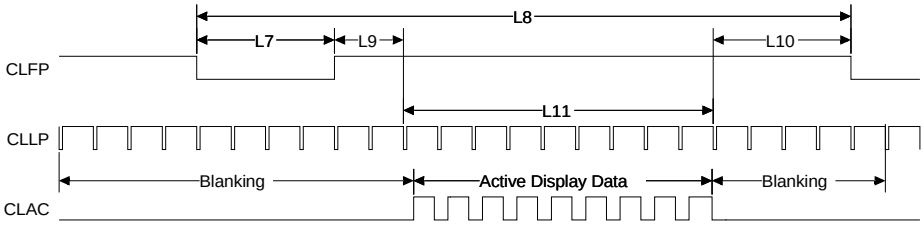


Figure 135: Vertical timing parameters for TFT displays

HSYNC vs VSYNC timing for STN displays

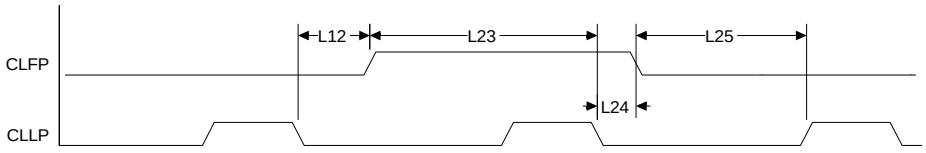


Figure 136: HSYNC vs VSYNC timing for STN displays

HSYNC vs VSYNC timing for TFT displays

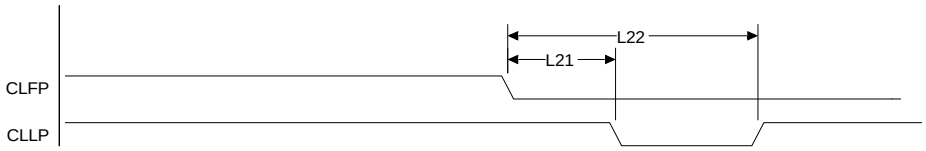


Figure 137: HSYNC vs VSYNC timing for TFT displays

LCD output timing

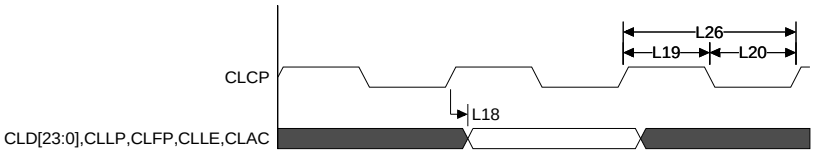


Figure 138: LCD output timing

SPI timing

Note: All AC characteristics are measured with 10pF, unless otherwise noted.

Table 494 describes the values shown in the SPI timing diagrams (Figure 139 through Figure 142).

Parm	Description	Min	Max	Units	Modes	Notes
SPI master parameters						
SP0	SPI enable low setup to first SPI CLK out rising	$3*T_{BCLK}$-10		ns	0, 3	1, 3
SP1	SPI enable low setup to first SPI CLK out falling	$3*T_{BCLK}$-10		ns	1, 2	1, 3
SP3	SPI data in setup to SPI CLK out rising	30		ns	0, 3	
SP4	SPI data in hold from SPI CLK out rising	0		ns	0, 3	
SP5	SPI data in setup to SPI CLK out falling	30		ns	1, 2	
SP6	SPI data in hold from SPI CLK out falling	0		ns	1, 2	
SP7	SPI CLK out falling to SPI data out valid		10	ns	0, 3	6
SP8	SPI CLK out rising to SPI data out valid		10	ns	1, 2	6
SP9	SPI enable low hold from last SPI CLK out falling	$3*T_{BCLK}$-10		ns	0, 3	1, 3
SP10	SPI enable low hold from last SPI CLK out rising	$3*T_{BCLK}$-10		ns	1, 2	1, 3
SP11	SPI CLK out high time	SP13*45%	SPI3*55%	ns	0, 1, 2, 3	4
SP12	SPI CLK out low time	SP13*45%	SPI3*55%	ns	0, 1, 2, 3	4
SP13	SPI CLK out period	T_{BCLK}*6		ns	0, 1, 2, 3	3

Table 494: SPI timing parameters

Parm	Description	Min	Max	Units	Modes	Notes
SPI slave parameters						
SP14	SPI enable low setup to first SPI CLK in rising	30		ns	0, 3	1
SP15	SPI enable low setup to first SPI CLK in falling	30		ns	1, 2	1
SP16	SPI data in setup to SPI CLK in rising	0		ns	0, 3	
SP17	SPI data in hold from SPI CLK in rising	60		ns	0, 3	
SP18	SPI data in setup to SPI CLK in falling	0		ns	1, 2	
SP19	SPI data in hold from SPI CLK in falling	60		ns	1, 2	
SP20	SPI CLK in falling to SPI data out valid	20	70	ns	0, 3	6
SP21	SPI CLK in rising to SPI data out valid	20	70	ns	1, 2	6
SP22	SPI enable low hold from last SPI CLK in falling	15		ns	0, 3	1
SP23	SPI enable low hold from last SPI CLK in rising	15		ns	1, 2	1
SP24	SPI CLK in high time	SP26*40%	SP26*60%	ns	0, 1, 2, 3	5
SP25	SPI CLK in low time	SP26*40%	SP26*60%	ns	0,1, 2, 3	5
SP26	SPI CLK in period	T_{BCLK}*10		ns	0, 1, 2, 3	

Table 494: SPI timing parameters

Notes:

1 Active level of SPI enable is inverted (that is, 1) if the CSPOL bit in Serial Channel B/A/C/D Control Register B is set to a 1. Note that in SPI slave mode, only a value of 0 (low enable) is valid; the SPI slave is fixed to an active low chip select.

2 SPI data order is reversed (that is, LSB last and MSB first) if the BITORDR bit in Serial Channel B/A/C/D Control Register B is set to a 0.

3 T_{BCLK} is period of BBus clock.

4 ±5% duty cycle skew.

5 ±10% duty cycle skew.

6 C_{load} = 10pf for all outputs.

7 SPI data order can be reversed such that LSB is first. Use the BITORDR bit in Serial Channel B/A/C/D Control Register A.

SPI master mode 0 and 1: 2-byte transfer

(see note 7)

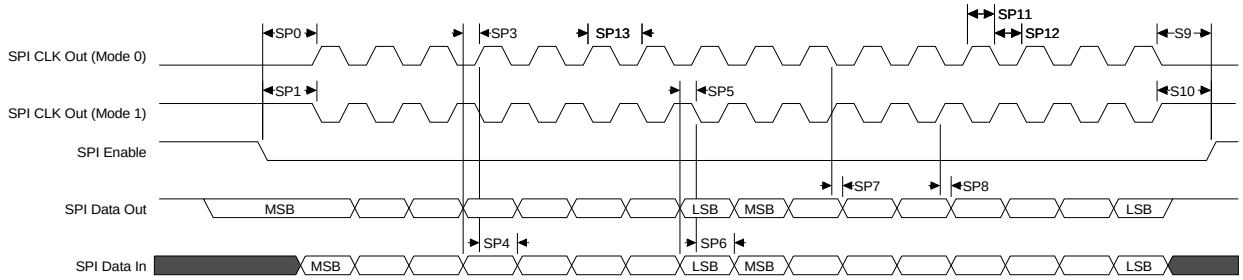


Figure 139: SPI master mode 0 and 1 (2-byte transfer)

SPI master mode 2 and 3: 2-byte transfer

(see note 7)

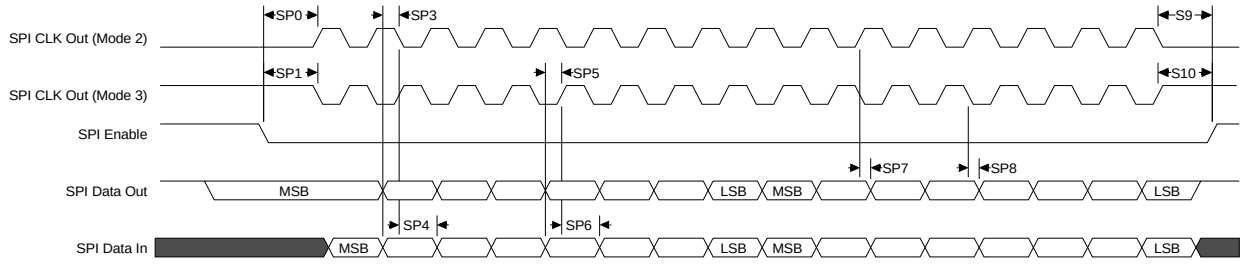


Figure 140: SPI master mode 2 and 3 (2-byte transfer)

SPI slave mode 0 and 1: 2-byte transfer

(see note 7)

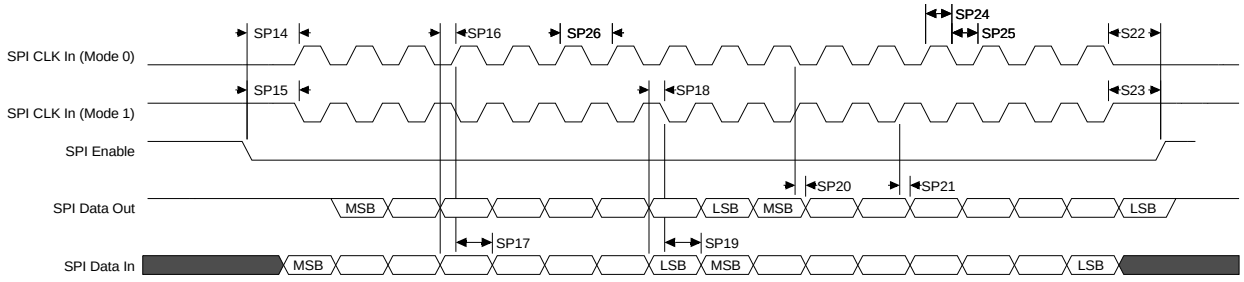


Figure 141: SPI slave mode 0 and 1 (2-byte transfer)

SPI slave mode 2 and 3: 2-byte transfer

(see note 7)

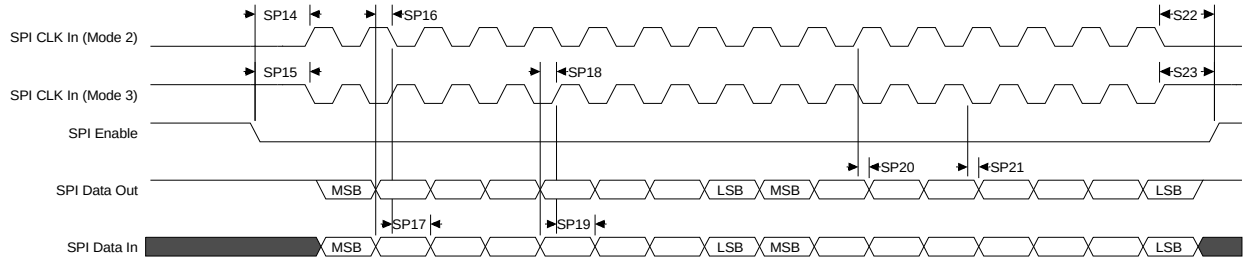


Figure 142: SPI slave mode 2 and 3 (2-byte transfer)

IEEE 1284 timing

Note: All AC characteristics are measured with 10pF, unless otherwise noted.

Table 495 describes the values shown in the IEEE 1284 timing diagram (Figure 143).

Parm	Description	Min	Max	Unit	Note
IE1	Busy-while-Strobe	0	500	ns	1
IE2	Busy high to nAck low	0		ns	
IE3	Busy high		1000	ns	2
IE4	nAck low		500	ns	3
IE5	nAck high to Busy low		500	ns	3

Table 495: IEEE 1284 timing parameters

Notes:

1 The range is 0ns up to one time unit.

2 Two time units.

3 Three time units.

IEEE 1284 timing example

The IEEE 1284 timing is determined by the BBus clock and the Granularity Count register (GCR) setting. In this example, the BBus clock is 50 MHz and the Granularity Count register is set to 25. The basic time unit is `1/50 MHz x 25`, which is 500ns.

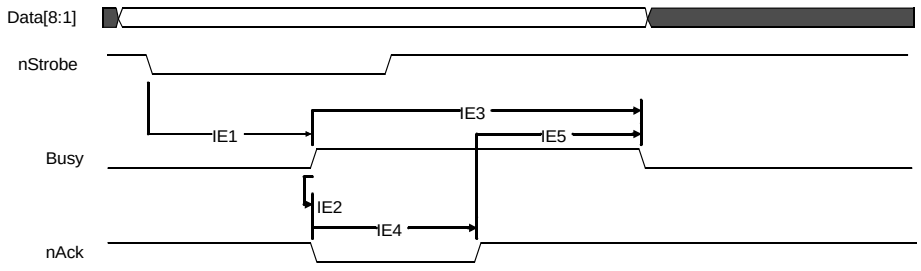


Figure 143: IEEE 1284 timing with BBus clock at 50 MHZ and GCR set to 25

USB timing

Table 496 and Table 497 describe the values shown in the USB timing diagrams (Figure 144 through Figure 146).

Parm	Description	Min	Max	Unit	Notes
U1	Rise time (10% – 90%)	4	20	ns	1
U2	Fall time (10% – 90%)	4	20	ns	1
U3	Differential rise and fall time matching	90	111.11	%	2, 5
U4	Driver output resistance	28	44	ohms	3

Table 496: USB full speed timing parameters

Parm	Description	Min	Max	Unit	Notes
U1	Rise time (10% – 90%)	75	300	ns	4
U2	Fall time (10% – 90%)	75	300	ns	4
U3	Differential rise and fall time matching	80	125	%	2, 5

Table 497: USB low speed timing parameters

Notes:

1 Load shown in Figure 145, "USB full speed load," on page 845.

2 U1/U2.

3 Includes resistance of 27 ohm ±2 ohm external series resistor.

4 Load shown in Figure 146, "USB low speed load," on page 846.

5 Excluding the first transition from the idle state.

USB differential data timing

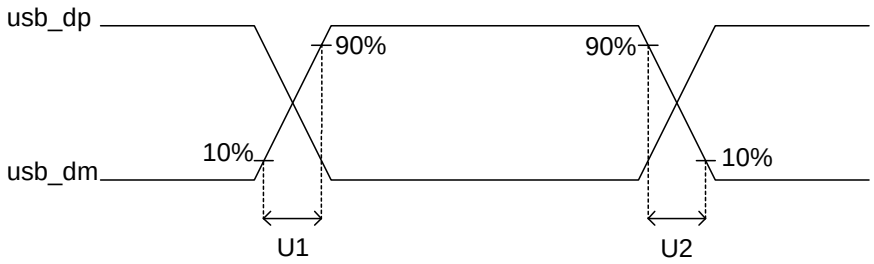


Figure 144: USB differential data

USB full speed load timing

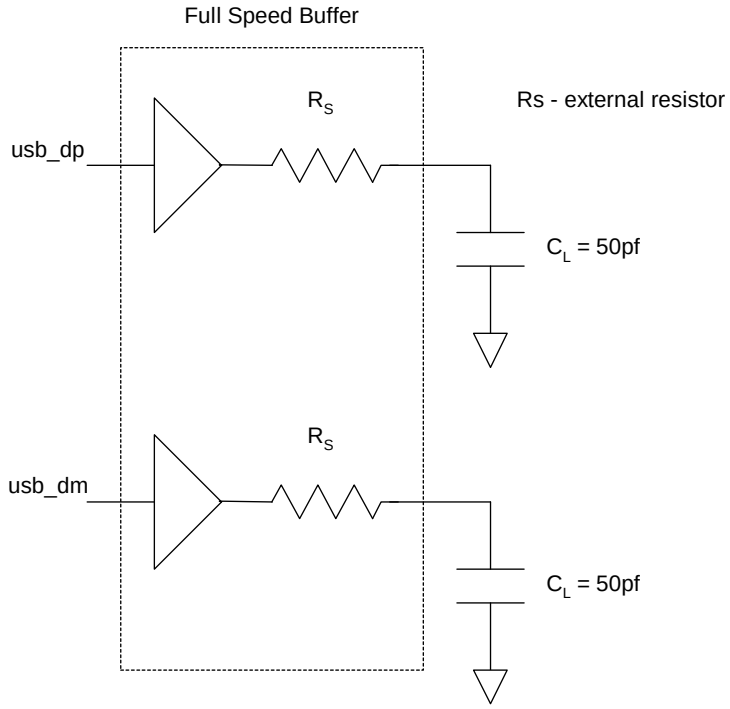


Figure 145: USB full speed load

USB low speed load

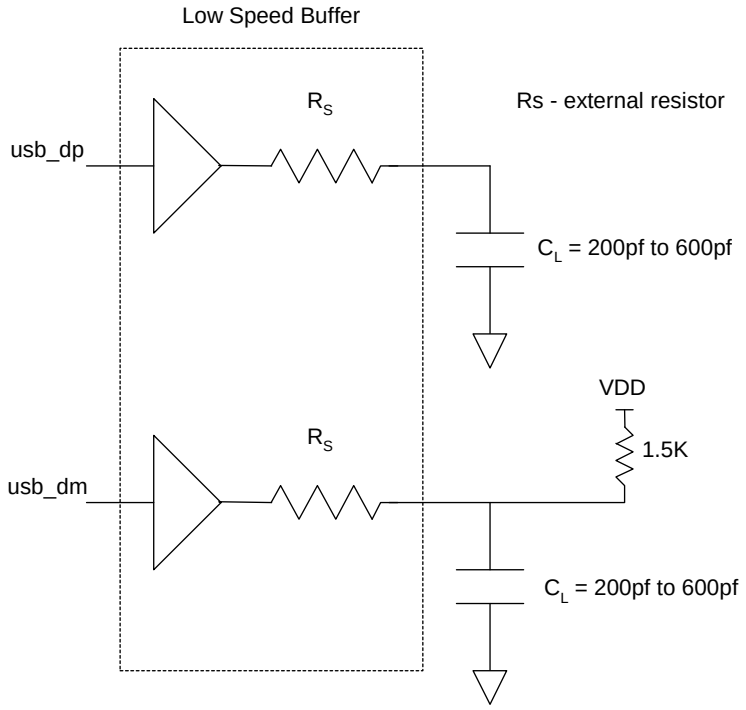


Figure 146: USB low speed load

Reset and hardware strapping timing

Note: All AC characteristics are measured with 10pF, unless otherwise noted.

Table 498 describes the values shown in the reset and hardware strapping timing diagram (Figure 147).

Parm	Description	Min	Max	Unit	Notes
R1	reset_n minimum time	10		x1_sys_osc clock cycles	1
R2	reset_n to reset_done		4	ms	

Table 498: Reset and hardware strapping timing parameters

Note:

1 The hardware strapping pins are latch 5 clock cycles after `reset_n` is deasserted (goes high).

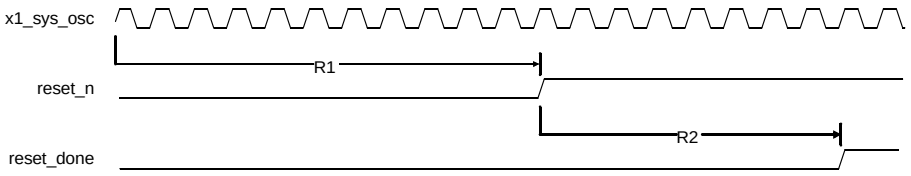


Figure 147: Reset and hardware strapping timing

- **R1:** `reset_n` must be held low for a minimum of 10 `x1_sys_osc` clock cycles after powerup.
- **R2:** `reset_done` is asserted 4ms after `reset_n` is driven high.
- The hardware strapping pins are latched when `reset_done` is asserted.

JTAG timing

Note: All AC characteristics are measured with 10pF, unless otherwise noted.

Table 499 describes the values shown in the JTAG timing diagram (Figure 148).

Parm	Description	Min	Max	Unit
J1	tms (input) setup to tck rising	5		ns
J2	tms (input) hold to tck rising	2		ns
J3	tdi (input) setup to tck rising	5		ns
J4	tdi (input) hold to tck rising	2		ns
J5	tdo (output) to tck falling	2.5	10	ns

Table 499: JTAG timing parameters

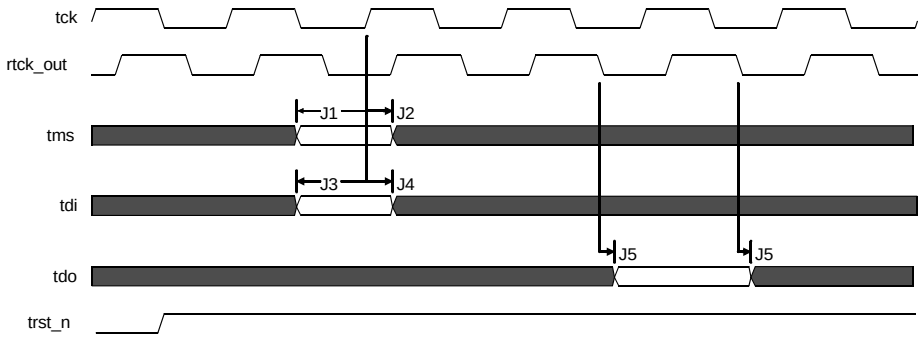


Figure 148: JTAG timing

Notes:

1 Maximum tck rate is 10 MHz.

2 `rtck_out` is an asynchronous output, driven off of the CPU clock.

3 `trst_n` is an asynchronous input.

Clock timing

Note: All AC characteristics are measured with 10pF, unless otherwise noted.

The next three timing diagrams pertain to clock timing.

USB crystal/external oscillator timing

Table 500 describes the values shown in the USB crystal/external oscillator timing diagram (Figure 149).

Parm	Description	Min	Max	Unit	Notes
UC1	x1_usb_osc cycle time	20.831	20.835	ns	1
UC2	x1_usb_osc high time	(UC1/2) x 0.4	(UC1/2) x 0.6	ns	
UC3	x1_usb_osc low time	(UC1/2) x 0.4	(UC1/2) x 0.6	ns	

Table 500: USB crystal/external oscillator timing parameters

Note:

1 If using a crystal, the tolerance must be ±100 ppm or better.

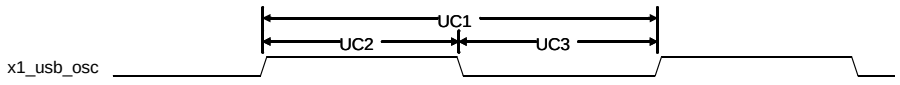


Figure 149: USB crystal/external oscillator timing

LCD input clock timing

Table 501 describes the values shown in the LCD input clock timing diagram (Figure 150).

Parm	Description	Min	Max	Unit	Notes
LC1	lcdclk cycle time	6.25		ns	1
LC2	lcdclk high time	(LC1/2) x 0.4	(LC1/2) x 0.6	ns	
LC3	lcdclk low time	(LC1/2) x 0.4	(LC1/2) x 0.6	ns	

Table 501: LCD input clock timing parameters

Note:

1 The clock rate supplied on `lcdclk` is twice the actual LCD clock rate.

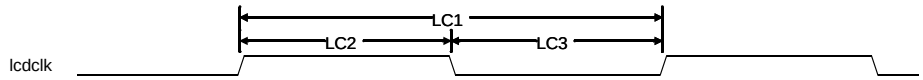


Figure 150: LCD input clock timing

System PLL bypass mode timing

Table 502 describes the values shown in the system PLL bypass mode timing diagram (Figure 151).

Parm	Description	Min	Max	Unit	Notes
SC1	x1_sys_osc cycle time	2.5	5	ns	1
SC2	x1_sys_osc high time	(SC1/2) x 0.45	(SC1/2) x 0.55	ns	
SC3	x1_sys_osc low time	(SC1/2) x 0.45	(SC1/2) x 0.55	ns	

Table 502: System PLL bypass mode timing parameters

Note:

1 The system PLL can be bypassed. In this mode, the CPU clock speed is 1/2 of `x1_sys_osc`.

2 The minimum high/low time on system clock input pin when used with an external oscillator is 1.5nS.

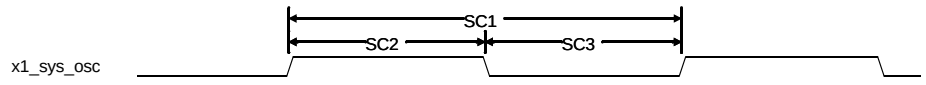


Figure 151: System PLL bypass mode timing

Packaging

CHAPTER 18

The NS9775 is a complete system-on-chip processor, and includes Ethernet, display support, and a robust peripheral set.

NS9775 dimensions and pinout are shown on the following pages.

Figure 152 displays the top view and dimensions of the NS9775. Figure 153 displays the side and bottom views and dimensions.

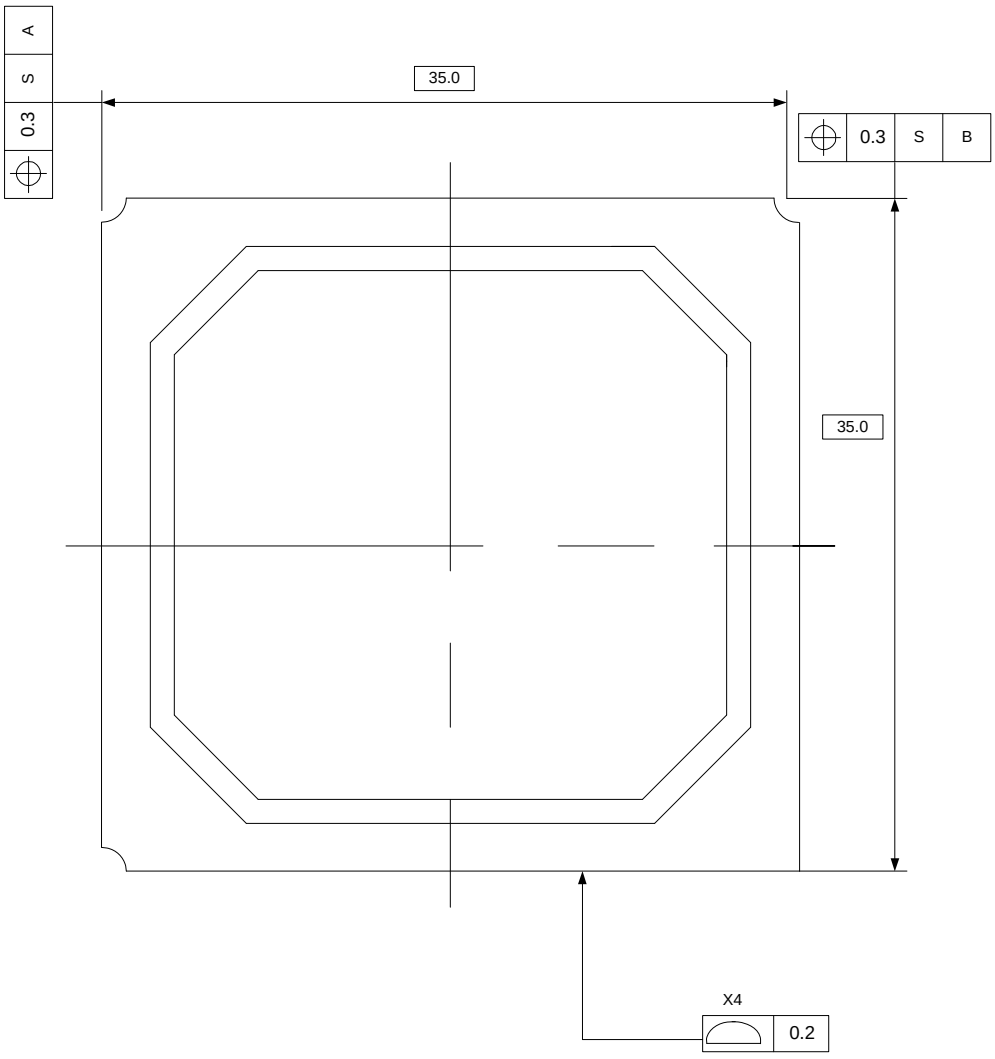


Figure 152: NS9775 top view

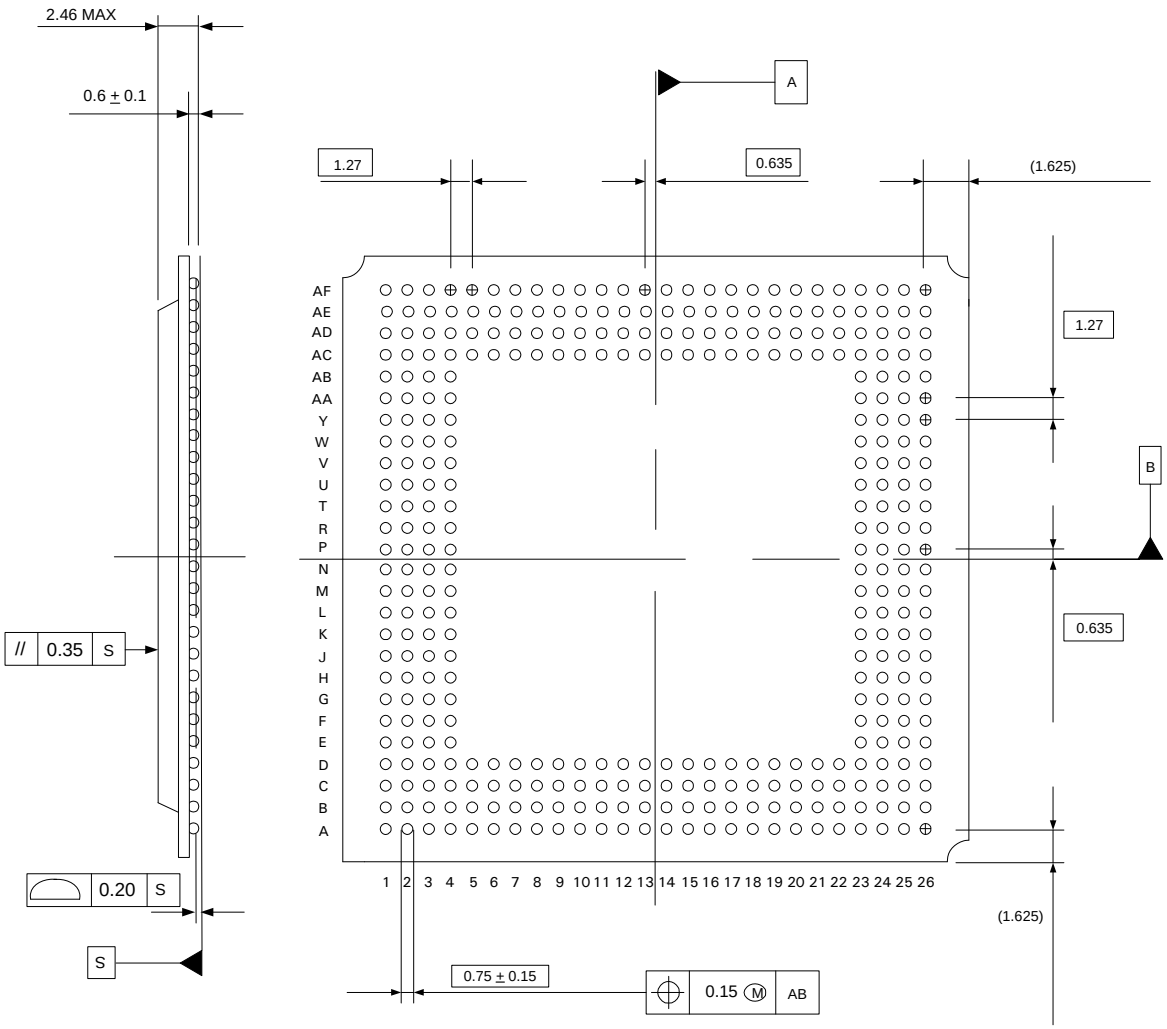


Figure 153: NS9775 side and bottom views

Figure 154 shows the layout of the NS9775, for use in setting up the board.

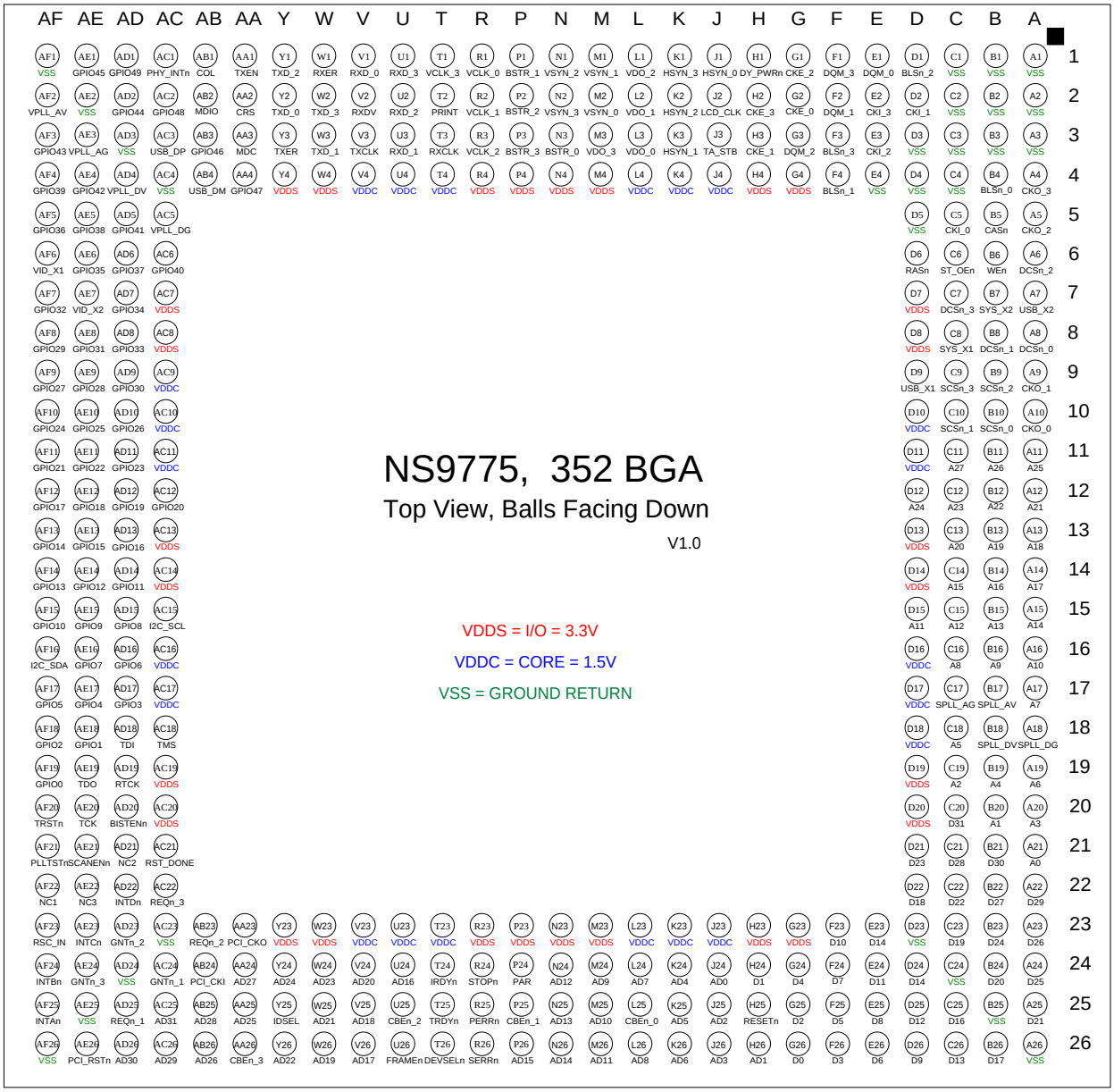


Figure 154: NS9775 BGA layout

Product specifications

These tables provide additional information about the NS9775.

ROHS substance	PPM level
Lead	0
Mercury	0
Cadmium	0
Hexavalent Chromium	0
Polybrominated biphenyls	0
Polybrominated diphenyl ethers	0

Table 503: NS9775 ROHS specifications

Component	Weight [mg]	Material		Weight [mg]	Weight [%]
		CAS no.	Name		
Chip	27.037	7440-21-3	Si	27.0370	0.61
Frame	1841.616	223769-10-6	Epoxy resin	865.5600	19.71
		7440-50-8	Cu	736.6500	16.77
		7440-02-0	Ni	9.2100	0.21
		7440-57-5	Au	1.8400	0.04
			Other	228.3560	5.20
Bonding wire	6.990	7440-57-5	Au	6.9900	0.16
Ag paste	3.400	7440-22-4	Ag	2.6200	0.06
			Epoxy, other	0.7800	0.02
Epoxy resin	1920.177	60676-86-0	Silica (SiO2)	1747.3570	39.79
			Epoxy, other	86.4100	1.97
			Phenol Resin	86.4100	1.97

Table 504: NS9775 materials sheet

Component	Weight [mg]	Material		Weight [mg]	Weight [%]
		CAS no.	Name		
Solder ball	592.400	7440-31-5	Sn	571.6700	13.02
		7440-22-4	Ag	17.7700	0.40
		7440-50-8	Cu	2.9600	0.07
Total weight	4391.620				

Table 504: NS9775 materials sheet

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